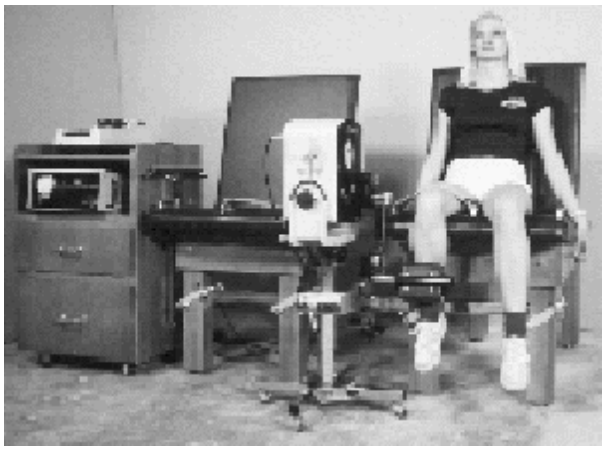
Strength Testing

As you might now guess, there are very few reliable tools used in exercise physiology. Worse yet is that the exercise physiologists do not appreciate the limitations of their tools. Machinists, engineers, chemists, and physicists typically reference their measuring tools in their formal papers. They state the known limits of accuracy of those tools and record and report only the data measured within the stated limits.

Exercise physiologists are not so disciplined and responsible. Most do not appreciate the difference between the precision and the accuracy of measurements. Precision is the agreement between successive measurements. Accuracy is the agreement between a measurement and its correct or accepted value. Although exercise physiologists are often schooled in statistics to some degree, they fail to realize that statistical method applied to measuring precision may merely reinforce their confidence in wildly inaccurate values.

This is the crux of the problem in all fitness-testing tools, particularly strength-testing tools. This is what Ed Farnham, long-time Nautilus general manager, was describing when he referred to the Cybex® (see picture below) as a "rubber ruler." Since ignorance of their limitations is widespread, isokinetic tools like the Cybex, the Biodex®, the Kinetron®, the Fitron®, the Kin Com®, the Chattanooga® and many others are ubiquitous throughout the realms of exercise physiology and physical therapy. But to understand why these products are not true measuring tools from a technical sense, it is important to understand the development of the MedX® testing tool.



A Cybex II used for leg extension/flexion strength evaluation/exercise. Nautilus purchased this machine in 1979 for $13,500. A short time later it sold for over $20,000. It enjoys widespread use among physical therapists as a testing tool to document muscular strength though it cannot qualify as a testing tool

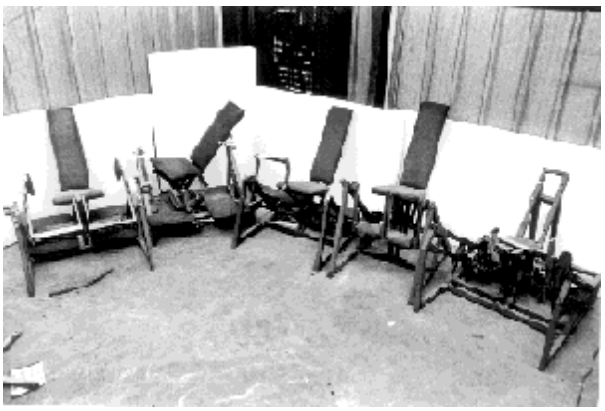
In the 1960s a PhD by the name of Karl Klien made comparative strength measurements of the quadriceps and hamstrings. Using a crude setup incorporating spring-tensioned analog tensiometers (so I have been told), he started the popularized notion that the ideal strength ratio between the quadriceps and the hamstrings is 60/40. Though a quantum improvement over Klien's crude apparatus, such tools as the Cybex are not so sophisticated to confirm such a ratio. And as Arthur Jones and I have maintained for years, such a ratio when used as normative data is not a practical reference for individuals.

In a frustrated quest to possess reliable strength measuring tools for Nautilus R&D, Arthur Jones set out in 1972 to spend millions to design and build such tools. Arthur and his associates conducted the original Nautilus West Point Project in 1975. One of the several batteries of before/after evaluations included strength tests using specially-constructed machines. Unlike Klein, Arthur built several (my guess = 8) heavy, steel testing machines. Each of these was like a Nautilus machine without a weight stack. Instead, each incorporated a fixed linkage and a mount for a tensiometer. Unlike Klein's, Arthur's testing machines were individually and specifically built to a particular muscle/joint function. But similar to Klein, Arthur

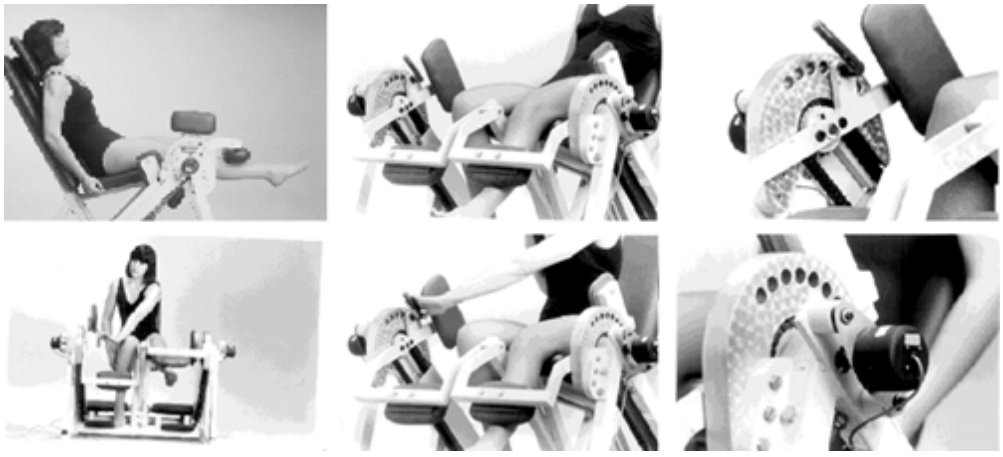
incorporated spring-tensioned analog tensiometers. Arthur's West Point tests made with these expensive tools were so unreliable that he discarded all of his strength-test data. Meanwhile physical therapists and exercise physiologists throughout the world were embracing the Cybex, using it in therapy and research. They were making Klein a celebrity.

I believe that I saw one of Arthur's prototype testing tools for the first time in late 1977. Nevertheless, I became very familiar with this most current version throughout 1978 and thereafter. I listened as Arthur discussed this machine with engineers Evan Muir and Jeff Zurco as well as with visiting physicians and others. I tailored my presentation after Arthur's to be able to demonstrate the merits of this tool on his behalf.

The tool of reference was for testing knee extension. Study the pictures below. This tool lacked a weight stack and functioned as an exercise machine in infimetric mode only. It incorporated a separate movement arm for each leg. Each movement arm's drive sprocket drove the opposite movement arm's drive sprocket in opposing rotations through a 7200-LBS-test double #40 chain. Beginning with the left movement arm, the chain ran to redirectional sprockets below and behind the subject, then to the right movement arm.



At left: evolutionary prototyping of a leg extension strength testing tool ongoing in the early 1970s by Arthur Jones. These were destroyed in 1987. Arthur used the somewhat finished version pictured below during the mid- to late-1970s to demonstrate the futility of isokinetic testing. This testing machine, which may still exist, was infinitely more precise than any commercially available testing tool, yet could not provide useful data. The same criticism remains true for almost all strength testing tools on the market today. Exception: MedX equipment.



Each movement arm could be optionally fixed in positions of 15-degree rotational increments by stabbing simultaneously through it with a 3/4-inch pin and through a 2-inch-thick aluminum hub possessing one of many 3/4-inch holes radially spaced in 15-degree increments. Fixation of one hub and its movement arm then facilitated static testing of the opposite quadriceps in 15-degree increments.

For example, if the right movement arm was pinned, the right movement arm was rigidly fixed. This gave the left leg a solid anchor against which to apply force through the left movement arm and chain. A force cell in line the chain (below and behind the frame) registered the magnitude to a graph recorder or digital output devices (later). To use this tool for the opposite leg, the hub pin was then switched to that side opposing that leg.

Although this tool could register force between the two legs as a dynamic, infimetric exercise was performed; dynamic testing was unreliable because positional reference was lost. There were other problems. These are best appreciated if we first analyze the problems of the static test.

In those years, we considered knee extension the most ideal function for application of a strength test. It was that function where we could best isolate the body part and isolate out the involved reactionary forces. After all, the pelvis and femur are relatively easy to constrain when compared to the lack of constraint possible in the shoulder girdle. Therefore, knee extension was the best function to start with.

Secondly, the tool was made of solid steel. Arthur once boasted that "You can drop this machine 10,000 feet onto solid concrete without hurting it." The Cybex machine warped dramatically with the most moderate of forces. Even so, this Nautilus prototype demonstrated an obvious 20-30-degree error in the positional reference for a moderately high force application from a strong athlete. This error in positional reference was due to stretching of the 7200-LBS-test chain — rendering the tool practically useless for accurate testing. This was no small error. A positional reference error greater than one degree is excessive. Since your muscle is stronger in some positions, weaker in others, a reliably repeatable positional reference is of paramount importance. And for the same reason, the positional error is different in different positions tested.

I underscore that the 20-30-degree error in this Nautilus prototype was evident to the naked eye. There were other less-obvious errors. The 20-30-degree chain stretch varied per force applied to the movement arm. Also, the solid-steel movement arms bent per force applied. Also, the pads compressed per force. Also, the flesh on the subject's shins compressed per force. Also, the bones of the lower leg bent per force.

Also, the readout was affected by the body torque of the lower leg. In this machine it was not possible — and in those years we believed it impossible — to account for bodytorque. Bodytorque is the torque created by the combined effect of mass, length, and mass distribution of the lower leg. (Pelvis stability was another problem, though I did not observe or write about this problem until 1984, and I neither saw nor heard anything about it from Arthur Jones until approximately 1991.)

Now appreciate that all of these mentioned sources of error are present in a static measuring mode — a mode used to simplify analysis of the muscles' contraction force per position. Next, go to fantasy land and consider the wildly uncontrollable sources of error in dynamic testing — acceleration, momentum, and that most nebulous of all factors — skill acquisition. Also, positional referencing is far more unlikely.

The problems of this early testing prototype lead us to several key conclusions:

• The errors in testing equipment must be reduced to the smallest possible value. Primarily this is related to three controls:

•The structural integrity of the machine

•Successful immobilization of the joints affected by common musculatures

•Body torque cancellation

• Once the error is reduced to the smallest possible value, we must know what that value is and adjust for it. For example: if X amount of force produces Y amount of positional reference error, the readout must instantly and automatically adjust using a formula for error per force.

• Only errors from static testing are reasonably controlled, accounted for, or adjusted for. Forget dynamic

testing! Don't even consider it!

This then put us in a dilemma. We indeed concluded that only static testing is valid. But what about Arthur's fundamental argument, "The Harder It Seems, The Easier It Is," whereby he eloquently explains that the first repetition of an exercise involves the musculature when it is most strong and therefore most capable of generating — into and unto itself — a damaging force magnitude? And now we propose to build testing equipment that requires a static, all-out effort of the first and only repetition?

I then (early 1980's) rationalized that static testing could be made safe if only the subject were properly instructed to apply the contraction force gradually and let off the force gradually. I temporarily deluded myself that the connective tissues surrounding the test site should not be at great risk. In addition, I then suffered the delusion that I was a master facilitator of information and that I could teach any subject competence in exercise equipment. I was incorrect regarding both these beliefs.

I was aware that an alarming number of West Point subjects had strained their hamstrings while performing the static tests in 1975. Arthur had noted that they seemed to incur the injury when they released the contraction abruptly. Hearing this, I concluded that if only I had been at the West Point Project, I could have prevented many of these injuries via proper instruction.

Imagine my embarrassment in 1982 when I strained my hamstrings during a static test. I was very mindful of the West Point injuries and was careful to apply as well as to unapply the contraction force. Yet I was injured. I limped around the Nautilus compound and got Arthur's attention. He appeared inquisitive but I gave him the high sign to avoid the topic in the presence of his audience of customers. I later explained what had happened and he proceeded to lecture me about his suspicions of the West Point injuries: abrupt termination of intense static contraction. I pleaded to him that I had indeed been careful and that still I had become injured. Arthur listened but made no further reply.

I thereafter was fearful of static testing. I was later concerned that I may have strained a brachial biceps during a static test (not certain, now doubtful). I then realized that due to fear, I was forever incapable of a valid static test on myself.

Worse yet, I found myself in an ethical dilemma. If I am aware of the dangers of static testing — although they are greatly diminished compared to the ballistic violence embraced by the dynamics of the isokinetics community — and I apply the proper, gradual buildup of contraction force and the gradual let-off of contraction force; and I still become injured; what is the probability of my successful conveyance of understanding and reasonable safety to one of my subjects? What is this probability through the myriads of other testing technicians who are virtual novices regarding the involved dangers?

My aspiration to work at and for Nautilus represents the most burning desire of the first thirty years of my life. As predictable, Nautilus had many attractions for me, but the most outstanding attraction was access to testing equipment that existed no where else in the world.

And it is somewhat ironic that — among many other reasons — I left Nautilus because I could not responsibly put subjects into harm's way. My dream had run aground. I now consider strength testing dangerous, even with a MedX machine — the eventual evolution of those early Nautilus prototypes.

I admit, even encourage, the use of the MedX machine on a restricted basis. It remains as the only true testing tool in exercise physiology. And it is vitally important to have such tools in research to determine the efficacy of exercise and physical therapy programs and treatments. The MedX is reasonably safe for research and serves as a practical tool in such settings where volunteer subjects are warned of its potential dangers. But once a so-tested research study confirms or denies the efficacy of treatment, it is unjust to expose the general

public at large to such unnecessary risks. The research treatment would then be already proven. We would know, by the research, that it works. There is now only one reason to expose a patient to the test and it is for the purpose of reimbursing the doctor and therapists through the insurer. The test is not in the interest of the patient.

[Several Guild members who run MedX testing programs disagree with my last statement. They believe, like I once did, that the test can be made safe, and that it is a worthwhile means in clinical evaluation and motivation, especially for lumbar conditions. We will hear from them in future newsletters. Also, Robert Francis is preparing (as of Spring 1996) a review of the strength testing tools used in the Battle Creek Sanitarium around the turn of last century.]

I have heard insurance adjusters and therapists state that the documentational tests are in the interest of the employee/patient. They argue that it is to "protect the patient" — to prove that he indeed possesses a healthy back before an occupational event or to document the fact that he should not be placed in particular activities. Arthur yet boasts that the MedX Lumbar test is a virtual lie detector — exposing malingerers. I do not believe any of this. Perhaps such testing is in the immediate interest of the employer or his insurer, but it is in no one's interest if the test presents a meaningful danger to the patient. And there are too many factors to consider in the evaluation of a so-called malingerer.

I sometimes hear it justified that such testing is motivational to the patient. Granted, such high-tech novelty is intriguing at first, but this wears off quickly, especially in consideration of the discomfort and confinement they experience in the MedX Lumbar and other MedX testing tools. Many patients come to dread being screwed into the constraints.

Danny Thompson keeps me current on MedX developments. In my opinion, Danny Thompson knows more about MedX testing than anyone else. Danny was intimately involved with the early MedX prototypes and research at Gainesville Health and Fitness and possesses detailed insight into the history and evolution of the MedX testing protocols. Presently, he is compiling this information in a pamphlet with accompanying suggestions for improvements of the testing protocol.

Danny Thompson is devoted to the MedX as a testing tool. Also, he is personally dependent on the exercise function of the MedX Lumbar machine for his back debilities. Nevertheless, Danny states that only 10% of those patients who suffer from back discomfort experience complete pain relief as a result of their MedX Lumbar exercise. He quotes this information from a survey conducted as part of one of the large University of Florida MedX research studies. Danny reports that this survey was not published with the remainder of the original study. Meanwhile, 80% — an impressive number — of the subjects report varying degrees of reduction in their pain. Danny is concerned that many private clinics may promote the MedX as a treatment that is dramatically effective in 80% of cases. MedX may strengthen the lumbars of this percentage, but dramatic strengthening commonly occurs with marginal pain relief.

Danny can also recite names and numbers of subjects who were injured by the MedX test. These injuries occurred both in research as well as in personal rehabilitation settings. Some injured subjects — some that are star examples of the benefits of the MedX exercise mode — were showing dramatic improvement in their back debilities just up until they incurred injury while performing the test to track their improvement. Again, the MedX Lumbar exercise is a godsend for many back patients. However, we believe that its testing function belongs restricted to the research lab.

I recently asked Danny his opinion regarding the safety of static strength testing in the MedX Lumbar. He replied: "If I administer the MedX test, I am uncertain of its safety. If anyone else administers the test, I am certain that it is dangerous. The difference lies in the MedX course to teach the technicians to safely administer the test. However, I do not believe that it can be taught with any reliability. My skills come only

with experience and intuition, traits which may never come to some instructors regardless of a week-long, formalized course."

Danny then asked me why I thought the test was dangerous. After referencing the "Harder It Seems, The Easier It Is" argument, I stated that there should remain a margin of safety between the maximum contraction force of a muscle and that tensile magnitude where the tendon or other connective tissue fails. Assuming a healthy structure and the avoidance of acceleration forces, the danger of exceeding the connective tissue integrity is reasonably low. However, we never really know that all of the 12 different lumbar muscle groups involved are healthy. And with a back patient we can assume that something is deficient. We never really know what is going on in there. We can not say, for instance, that maximum force output by one structure does not gravely compromise another structure. I believe that most new patients do not know how to intensely contract their musculature — specifically, here, their lumbar. Due to this they may also be unable to perform a valid test. As they learn to nervously and willfully generate a truly maximum force, they come closer to effecting a legitimate test. They may also be learning to hurt themselves.

This seems to be the case with Greg Burns. Greg is a Guild member and the owner of several MedX products in California. Although Greg understands proper loading and unloading procedure and safety, he recently hurt his back while using the MedX Lumbar machine to determine his fiber type. Greg's injury was ridiculously unnecessary. Again, who needs to know his fiber type? What value could it possibly be? And to injure yourself on behalf of a trivia question?!

The impetus to test is part of the medical bureaucracy. The insurers have been convinced by mainstream medicine that documentation of medical services is prudent. It is more or less believed that tested proof must accompany any bona fide medical remedy. Although Western medicine is opening its eyes to the notion that the intangible (fringe medicine) may have real remedial effect in many conditions and diseases, the stigma of charlatan still resides with remedies devoid of documented proof — i.e., a test.

Equipment such as the MedX is too expensive to sell to most university researchers unless, it can also be marketed to the medical clinicians as well. To illustrate, suppose that the MedX Lumbar required $20 Million to design, test, patent, and begin manufacturing. If you then suppose that there are fewer than 80 research labs in the world that can afford to spend a quarter million dollars on such a tool — assuming, of course, that they will all buy one — the enterprise is a financial bust. But if you can lower the price by selling more and faster to practicing therapists and doctors, then the price attracts a much larger potential market.

An exercise-mode-only MedX Lumbar machine might cost 10 times as much as the typical industrial grade exercise machine on the market today. And to break into a market with such a price tag, it seems necessary to incorporate muscle testing capability. Such tests are the currency of the industry and not likely to go away just because Arthur or I condemn them. They are part of the magic of sportsmedicine and are strongly alluring to all of the personalities involved in the therapy enterprise. <Picture>

In early 1996 MedX made the MedX Lumbar machine available for $25,000 - a price less than half its previous cost. Perhaps some of the aforementioned dilemmas will be ameliorated.

Strength testing is interwoven with muscle fiber typing. Please read pages 59-60 in the Super Slow Technical Manual to review my criticisms of the subject. In short, there are different muscle fiber types in humans. So what? This does not suggest any practical conclusion regarding the effects of how exercise is performed.

In the past, Arthur has strongly bucked the notion of fiber

typing, and it is my personal belief that he silently scoffs at it still. But by Arthur's personal guideline, "You don't sell pews to a Catholic by pointing out that the Pope is a fag." Fiber typing is the religion of the physical therapist. It allows him to feel academic and delusional about being a real person of science and technology. It might be OK to take his Cybex (isokinetics) away but you had better let him keep his religion.

I asked Danny Thompson regarding Arthur's real opinion of fiber typing. Danny said that he could not be certain, but he notes that Arthur's writing or verbal presentations are filled with hedges — ". . . might be . . . could be . . . perhaps is."

I really do not know this, but it appears that Arthur has marketed MedX to let the physical therapists keep their fiber-typing religion intact. Meanwhile, he attacks the isokinetics mentality and makes it out to be the virtual Devil. [As I do, Arthur likes to quote Eric Hoffer. In The True Believer Hoffer states, "Mass movements can rise and spread without belief in a God, but never without belief in a devil."]

Arthur attacks isokinetics primarily regarding its dangers of ballistic movement and its unreliability for measuring. On these points, I could not agree more. I also admit that without Arthur's marketing savvy, perhaps such a valuable exercise would never have become available to those who need it so much. I only wish that the fervor to perform muscle testing can be quelled to a reasonable level.

While I believe that the MedX Lumbar machine is an extremely valuable research tool and long overdue in our industry, I am sternly opposed to the MedX Cervical machine. in my opinion, Arthur made several serious mistakes with this design.

The correct use of the Nautilus 4-way Neck machine was studied and refined by me and my co-workers at Nautilus. I performed this work for Arthur and at Arthur's expense, although he never expressed an interest in what we discovered.

At the same time in another part of the company, new designs of this machine were emerging that contradicted our observations concerning proper form and protocol. One of these contradictions was the incorporation of a swivel head pad.

The swivel head pad was a bad idea, one still used in neck machines manufactured by several companies today. [Nautilus' competition would sometimes copy our discarded ideas. Later Nautilus owners copied back these ideas with the belief that they were playing catchup in the market.] I believe that at one time I privately considered it as an improvement over the original 4-way Neck incorporating a fixed head pad.

Then I encountered the swivel head pad at the Osteoporosis project. The swivel caused such complication in the subjects' proper flexion/extension that the machine was returned to the factory and replaced with the original version.

It is appreciated by very few instructors that, during active extension, the head and neck and most of the spine must be permitted to extend in concert. This is a principle of spinal function. In so doing, the chest moves forward as the head moves backward as though the head and buttocks might touch. For the machine to properly accommodate the body's movement, it is imperative that the user possess feedback from the head pad in such a way that he ensures the movement are remains in the same relationship to the head at all times. This feedback resides exclusively in keeping the headpad on the same position on the posterior skull.

If the headpad is made to swivel, then this feedback is lost. Also the swivel head pad, rather than accommodate incorrect form - one of it's purported purposes - either crawls up the subjects head or down his

neck to flip under the head.

Arthur's first boo-boo was that he violated his own sacred principle:

Function Dictates Design

He designed the MedX Cervical so that the upper torso is pinned with chest pads against a concave backpad, thus preventing extension of the thoracic spine as the head and neck actively extend. Sure, I understand that stabilization of the torso is mandatory for accurate testing to occur, but to prevent the spine its normal unitary function obviates a valid tool as well. With the MedX Cervical machine, Arthur is guilty of making one of the mistakes in principle (almost) he correctly accused Cybex of committing: The Cybex knee function disallowed complete extension due to violating the principle of active sufficiency; therefore, the Cybex effectively purported to measure extensional positions it simultaneously prevented due to inadequate hip extension in the seat to seatback angle. Arthur purports to measure the extremes of neck extension while partly preventing these extremes; however, the sufficiency principle is not exactly the same in the spine as in the knee. This needs greater clarification.

Note that the sufficiency principle as explained on page 124 of The SuperSlow Technical Manual applies to the appendicular skeleton. It does not necessarily apply to the axial skeleton. [By the way, I did not realize these nuances until I became intrigued with trying to explain Arthur's Cervical machine mistakes.]

When performing active extension of the neck, the various intrinsic extensor muscles run varying distances down the spine. Some cross only one intervertebral joint. Some two. Some go halfway down the spine. Unlike the need to place a muscle in a slight stretch across one joint (hip) to obtain meaningful contraction across the intended (knee) joint as during leg extension; the intrinsic spinal erectors do not obey such a principle. The spine is designed to extend as a unit. Not so the leg.

Later, I believed I might be guilty of an inconsistency. During active cervical flexion, I have always demanded rigidity of the torso with the chest held high as the chin approximates. Should not I permit the entire spine to flex as a unit if I demand that the entire spine extend as a unit? If so, I have a real mess attempting to isolate cervical flexion from torso flexion. However, note that the cervical flexors are not intrinsic to the spine. They are origined on the clavicles and ribs, not the spine, while the spinal extensors are both intrinsic (spinae erectors) and extrinsic (trapezius, levator scapula).

I first encountered the MedX Cervical machine about five years ago. I then realized that the swivel head pad was incorrect, but I was taken by surprise with Arthur's sufficiency mistake. Two very light repetitions froze my neck for two weeks. The thoracic spinae erectors were in spasm this entire period. Of course, I possess congenital cervical problems. So will many of the subjects using the MedX have cervical conditions of one kind or another.

It is my personal opinion that:

•Arthur does not possess the necessary knowledge of proper cervical exercise to build a proper cervical machine.

•The present MedX Cervical is potentially dangerous and does not constitute a tool to properly test cervical function.

•Arthur should remove the machine from the market and recall all units in the field to save his reputation.

Of the many physical therapists who visited Nautilus during the time I was there - as well as before and after - I encountered only one whom we convinced the Cybex was worthless as a testing tool. This therapist was not

easily convinced, but after much protracted - but detached - debate, he conceded that the several Cybex tensiometers he purchased for his hospital were worthless.

Being pleased that we finally had found an intelligent physical therapist who could technically analyze his mistakes, we apprised Arthur. He then replied cynically to the effect that, "Now do you really believe - even though you may have convinced him academically of the Cybex sham - that he is going to his hospital board of directors and admit to them that he has mistakenly wasted $60,000 of their money?" Of course not.

By the same Jonesian argument, there are several hundred MedX Cervical machines in the field. They are used in clinical and research settings. The MedX Cervical technicians have made a substantial investment of time and money to incorporate these tools into their businesses and mindsets. How many of them will doubt their application and soul search with a reading of this newsletter? - Most will merely rationalize away the inconsistencies.