

What is Osteoporosis? Statistics & Facts

Osteoporosis is a disease that affects millions of Americans. As defined by the National Institute for Osteoporosis, it is a “disease characterized by low bone mass and structural deterioration of bone tissue, leading to bone fragility and an increased susceptibility to fractures, especially of the hip, spine, and wrist, although any bone can be affected.” (National Osteoporosis Foundation, [NOF], 2008). The affects on the hip and spine are extremely serious since the nervous system innervates the spine, a fracture to the spine can prove fatal, or at the very least debilitating and painful, where as a fracture to the hip almost always results in hospitalization, and can permanently impair the ability of an individual to walk.

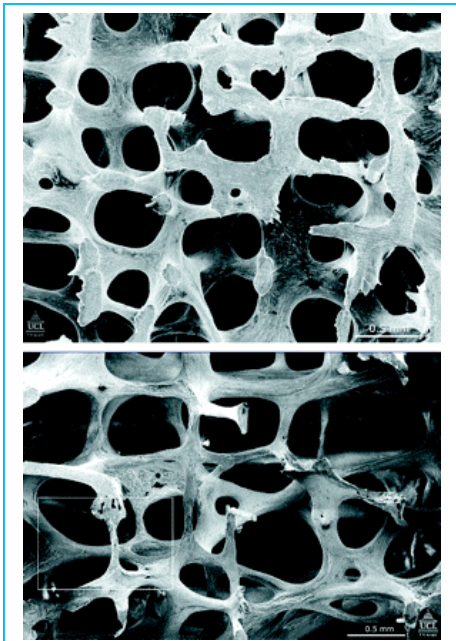


Figure 1: The electron micrograph slide image on the top represents L3 vertebrae in a 31 year old woman, and the image on the bottom in a 70 year old woman. Source: Article by Poole and Compston in BMJ (2006).

Bones are made up of an organic component (collagen protein), an inorganic component (calcium phosphate hydroxide apatite, $\text{Ca}_{10}(\text{PO}_4)_6(\text{OH})_2$), and living bone cells. Bone collagen, a triple helix of braided fibrous protein, provides a strong, flexible frame with spacing every 64 nano meters, into which the apatite mineralizes providing hardness of bones. Living bone cells called osteoblasts, osteocytes and osteoclasts are responsible for bone turnover (Young, 2009). Osteoblasts build new bone upon impact where as osteoclasts take away old bone.

Osteocytes serve as a messenger between the two, telling new bone where to lay down its new path, and old bone where to disappear. It is very important to keep these cells balanced so that bone is turned over as evenly as possible and not dissolved more efficiently than it is replaced. The systems of bone building and bone replacement are not co-regulated in adulthood. It is very important to keep the systems of bone collagen synthesis and bone apatite mineralization carefully balanced. Over-mineralized bone is very brittle and is broken easily. Under-mineralization of bone does not provide enough support for an adult body and therefore can cave easily.

By the time we finish puberty (approximately age 18yrs for girls, 20yrs boys); we have 85 – 90% of our bone mass. This means that an individual only has the opportunity to grow another 10 – 15% more bone over the course of our life (NOF, 2008). While we turn over bone our entire lives; it slows with age, and we will never once again have an opportunity to have such a deep impact on our bone density. This is why it is so crucially important for children to become physically active at a young age, intake enough calcium, and why it may be important for them to take part in age appropriate strength training programs.

When women go through menopause, the hormone estrogen for the mostly disappears from the body (though it is still produced in very low amounts by the ovaries). Estrogen is important to preventing bone loss as it essentially blocks the body – specifically the parathyroid – from acting on the bones to find calcium. Estrogen as a hormone sends out a signal that redirects the body to absorb calcium from the intestines rather than from the bones. When it occurs in the body in small doses such as in

menopause there is nothing to block the signal, and as such it leeches calcium from the bone thereby degrading the mineralization crystals.

Calcium is important not only to bone density but also to muscular contraction, brain function, and blood clotting. A lack of it can spearhead an entire downward spiral of events including a slowing of brain function, a slower response of muscular fiber recruitment in movement, and of course, bone loss. According to the National Osteoporosis Foundation, women are four times more likely to be affected by this disease than men. It is currently a major public health threat for an estimated 44 million Americans, or 55% of individuals over the age of 50. Of this 44 million, 10 million are estimated to already have the disease and 34 million are estimated to have low bone mass placing them at increased risk for osteoporosis. Popular belief is that osteoporosis is a disease that only affects women, but this is not the case, of the 10 million individuals estimated to have osteoporosis eight million are women, but 2 million are men (NOF, 2008).

In 2005, osteoporosis accounted for more than 2million fractures including approximately: 297,000 hip fractures, 547,000 vertebral fractures, 397,000 wrist fractures, 135,000 pelvic fractures, 675,000 fractures at other sites throughout the body. The number of fractures due to osteoporosis is expected to rise to 3 million by 2025 (NOF, 2008).

Bone loss and the fractures that can possibly occur from them are very serious and often fatal. An average of 24% of hip fracture patients over age 50 die in the year following their fracture. Six months after a hip fracture, only 15% of hip fracture patients

can walk across a room unaided. Mortality is also an issue; in 2005 alone a total of 15,802 people over the age of 65 died from result of injuries from falls (NOF, 2008).



Figure 2: This image shows a fracture in the femoral neck. Source: Article by Poole and Compston in BMJ (2006).

Current trends in measuring for Osteoporosis

Individuals cannot feel their bones becoming weaker. It is often only after a fracture that osteoporosis is diagnosed. Osteoporosis is also commonly discovered after a serious fall, or upon close examination of continuous back pain, or spinal deformities such as kyphosis.

Bone mineral density tests have become the gold standard for measuring bone loss. A standard bone mineral density (BMD) test will measure bone density in various sites of the body, although portable versions of this machine will only measure sites (typically at the calcaneus). The densitometer exposes bone to a minimal amount of x-rays and measures density of bone by noting the decrease in radiation to pass through the bone. It is actually best to measure the lumbar vertebrae and the hip which can only be done on a non-portable unit. Experts recommend a type of BMD test using a central DXA (which stands for a Dual energy X-ray Absorptiometry). The DXA utilizes 2 x-rays beams with different energy levels aimed at the bone which better enables subtraction of soft

tissue. A DXA can measure bone density and help predict the probability of a fracture, as well as whether or not a person's bones are losing density or staying the same over a period of one year. Primarily a DXA test will look at the bone density of the hip and spine since these are the two most common locations for bone loss, though occasionally the forearm will be used, when the spine and hip are not logical places to test. DXA utilizes a rating system that is based on a T-score. Osteoporosis is defined as a T score that is -2.5 or below. This 2.5 is the standard deviation based off a standard 20year old adult of the same sex. A T score of -1.0 or greater is considered "normal" and -1.0 to -2.5 is termed osteopenia. Osteopenia is defined as less than ideal bone mass, which can be a precursor for Osteoporosis. It is often recommended individuals with osteopenia begin taking medications to help prevent further bone loss. Currently the US Preventative Services Task Force (USPSTF) recommends that all women age 65 and older are screened with bone densitometry, and that those at risk for osteoporosis get screened by age 60 (US preventive Services Task Force, 2002).

In addition blood test are often ordered in order to help identify the underlying cause and to diagnosis whether bone loss is simply from aging or whether there is a more serious underlying cause such as cancer, Cushing's disease, or other kinds of diseases that affect the blood and as such the bones. Blood is a transport system for lots of things in the body including calcium ions. Body will transport the calcium to a bone building site when it's needed for mineralization. As with any solution, there is a maximum solubility. This means that if an excess of calcium ions is in the blood – driving the concentration too high – it will precipitate or deposit out (i.e. find anions and form solids). If these solids form in the blood vessels, they can inhibit or even block flow, and

potentially cause a clot. In terms of osteoporosis when the body leeches calcium from the bone, it ends up transporting that calcium in the blood. So someone with osteoporosis would have an increased susceptibility to blood clotting problems.

Risk Factors and The role of Diet and Lifestyle in Osteoporosis

Particular ethnicities appear more at risk than others. Currently, the occurrence of osteoporosis is growing most rapidly in women of Hispanic heritage. The NOF expects that within the Hispanic population alone, that osteoporotic fracture costs will increase from an estimated \$754 million in 2005, to over \$2 billion per year in 2025. In addition Caucasian, Asian, and African women are at risk (NOF, 2008).

In general, women as a whole are at risk. Osteoporosis affects four times more women than men. Women can lose up to 20% of their bone mass in the five to seven years after menopause. Smaller framed women are at higher risk.

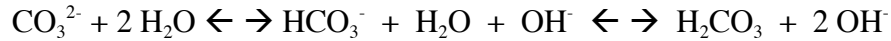
Individuals with low sex hormones, including women who have low amounts of estrogen, or who are prone to amenorrhea (missing periods) are at a higher risk for developing osteoporosis. This is also true for men with low levels of testosterone or estrogen. Individuals that have anorexia nervosa, rheumatoid arthritis and gastrointestinal diseases may also be more susceptible to bone loss. In addition, certain medications, such as steroids and anticonvulsants, can cause bone loss.

Smoking and tobacco use is another risk factor for osteoporosis. Tobacco often causes lower body weight, early menopause, and increased breakdown of estrogen that comes from medication or other forms outside the body. In addition smoking inhibits the bone building cells, osteoblasts from doing their job (Wong, Christie, and Wark, 2007).

Nutrition and lifestyle seem to play a key role in bone loss. Individuals, who are not receiving adequate nutrition, have low calcium intake, vitamin D intake, or an excessive intake of protein, sodium, and caffeine are considered at risk. The National Institute of Osteoporosis recommends that individuals intake 1000mgs of calcium daily, and post menopause 1500mg daily. In 1998 a study was completed that showed that ingesting 1200 – 1500mg of calcium a day, and 7—to 800 IU of Vitamin D reduced the fracture rate in post-menopausal women by 50% (Sparrowe, 2002).

However, despite how much calcium you intake, it is entirely possible that your body will not absorb it, especially in the case of a poor diet or in the case of lactose intolerance. Lactose Intolerant people are at a higher risk for bone loss because they lack the enzyme lactase which is necessary for the breakdown of lactose that occurs in dairy products. Supplements, lactase drops, or other types of foods are needed (National Institute of Arthritis and Musculoskeletal and Skin Diseases [NIAMS], 2009). As far as diet goes, when the body is deficient in either calcium or Vitamin D, calcium regulating hormones are affected resulting in a lower concentration of circulating ionized calcium. This will cause an increase in secretion of PTH (parathyroid hormone) from the parathyroid gland. This increase of PTH level will cause an increase in bone remodeling which in turn can lead to significant loss of bone mass (Nieves, 2005). When there is not enough calcium coming from the diet it is recommended to take a supplement especially after the age of 50. The average US diet contains only 600mg of calcium a day which is far below recommended intake of 1000 – 1500mgs (Wright, Wang, Kennedy-Stephenson, Ervin, 2003).

There are different forms of calcium supplements, and in order to maximize calcium uptake it is recommended that several doses are taken throughout a day without anyone dose exceeding 500mg, because the greater the calcium load the lower the absorption (Nieves, 2005). Also, calcium is more readily absorbed with food. Calcium carbonate contains more calcium per tablet (40%) than some of the other forms such as calcium citrate (23%) (Institute of Medicine, 1997). However, percentage of calcium in the tablet may not directly correspond to absorption within the body. Calcium citrate $[\text{Ca}_3(\text{C}_6\text{H}_5\text{O}_7)_2]$ is a much better delivery of calcium to the body than Calcium carbonate $[\text{CaCO}_3]$. Calcium citrate dissolves much more completely making more calcium accessible. Calcium citrate has an organic anion, in fact, the exact same anion as citric acid (i.e. Vitamin C) and your body can use this as well. Calcium citrate already is in a form the body uses as food. Calcium carbonate (e.g. seashells) does not dissolve completely. And what of it does dissolve changes the pH of your blood, as well as releases CO_2 into the blood stream changing osmotic pressure. In water carbonate picks up hydrogen and releases hydroxyl groups making the pH of the blood higher (i.e. more basic) (See chemical equilibrium equation below). Additionally, this anion does not serve the body as the citrate does. All functioning bodies have plenty of carbonate generated through eating absolutely anything as it's the ultimate byproduct of the Citric Acid cycle. When bodies break down any kind of food for energy – all carbohydrate, all lipid, and all protein ultimately converge in the citric acid cycle and generate carbonate. It's never needed in a supplement and is totally useless. Citrate, related to vitamin C, is an excellent and needed supplement (Young, 2009).



It is possible to get enough calcium from your diet if carefully planned. Due to the body's natural ability to digest food, this may prove to be a more effective manner in receiving calcium. There are many foods that are rich in calcium such as fortified oatmeal, cheese, tofu, soy, miso, seaweed, dark green vegetables, fish with bones, and some kinds of nuts. Herbs that contain calcium include nettles, horsetail, sage, oat straw, borage, raspberry leaf, alfalfa. Interestingly, there is some evidence that vegetarians may have be better equipped to prevent bone loss. A study in Michigan suggested that women who were vegetarians for 20years only had 18% bone loss versus the higher percentage found in women who were meat eaters. Sparrowe, the author that cited this study, suggests that this is due in part to the fact that "a diet too rich in animal protein can cause the body to excrete too much calcium into the urine" (Sparrowe, 2002). However, this biochemically suspect. It shows a possible reflection on Sparrowe's part, who is not a biochemist. Also, it should be mentioned that a search for this study on several medical journal sites yielded no results, though that does not mean that the study did not occur. It should be considered that this may have been an informal study not a scientific study. In addition, Sparrowe may have been biased, as she is a well known yoga instructor. Yogi's are long known for often having and promoting vegetarian diets and lifestyle, and this study was cited in a yoga related journal. If the study did exist it was conducted over a very long period of time, and long term vegetarians tend to be extremely health conscious, and often maintain healthy lifestyles probably with excellent

levels of physical exercise which may be why their bones fared better – not necessarily because of the diet. There is not a biochemical path for dragging calcium out in urine with animal protein. The body simply does not function in this manner (Young, 2009). In addition, a diet lacking in animal protein can very easily be deficient in essential amino acids which would halt the production of bone collagen. If the bone collagen is not there, the body can't replace bone and also, it won't allow calcium apatite (the hard crystals that make bone strong) to deposit (Young, 2009). This could lead to thinner weaker bones and/or more brittle bones because of the imbalance between the mineral component and the organic matrix. In short, biochemistry looks at a vegetarian diet as being a danger to bone health, among other things.

In addition to calcium, the body needs other nutrients to prevent bone loss including adequate amounts of Vitamin D. Calcitrol, often referred to as the “active Vitamin D” cannot be formed in adequate supply in the body. This will result in insufficient calcium absorption from the diet. Vitamin D can be obtained, through the skin (via sunlight), from diet, and from supplements. Fifteen minutes in the sun several times a week without sunscreen is recommended for most people to create all the stores of Vitamin D they could possibly need. If supplementation is needed 400 – 600 IU are recommended. It can also be found in egg yolks, saltwater fish, liver, fatty fish, and fortified dairy products and juice (NIAMS, 2009).

There are other important nutrients to preventing bone loss. It is speculated that Vitamin K, a fat-soluble vitamin, which is involved in blood coagulation, may also play an important role in preventing bone loss. Vitamin K facilitates carboxylation of proteins such as Osteocalcin, which plays a role in mineralization during bone formation and

calcium ion homeostasis reducing urinary calcium excretion(Booth, 1997). Vitamin K can be found in dark green leafy vegetables, fruits and vegetable oils with small amounts in dairy and grains.

In addition, potassium may be important to bone density, particularly in prevention of the excretion of calcium. Potassium is easily found in many vegetables and fruits, legumes and milk. There is some evidence that an increase in potassium citrate lessens bone loss for individuals who have high salt diets (Harrington, 2003). Salt causes an increase in excretion of calcium by the kidneys. It is believed that higher salt intake leads to an increased level of parathyroid hormone and greater rates of bone loss in postmenopausal women and men (Harrington, 2003). The optimal intake of calcium according to the American Heart Association is 2400mg a day for a high salt eater. If calcium requirements are met that a more liberal use of sodium can be used (Nieves, 2005).

Other supplements that may be important are Vitamin C which is an essential to collagen formation and Vitamin A which is essential to bone remodeling. It should be mentioned though that excessive Vitamin A intake may be detrimental to bone and kidney health. Essential minerals such as magnesium, copper, manganese, zinc and fluoride are often lacking in postmenopausal women and important to bone growth. In addition, hydrochloric acid decreases in the stomachs of postmenopausal women making it difficult for women to digest protein needed to build up bone collagen.

Caffeine and alcohol may play a role in bone loss. Some researchers believe that consuming more than 3 – 4 cups of caffeinated coffee a day can increase your risk factor

by 80%, and that alcohol plays a role in bone loss, though both have yet to be proven (Sparrowe, 2002).

Current Trends in Medication

There are three basic means of preventing bone loss through medication: hormone replacement therapy, antiresorptive medication, and bone forming medications.

Hormone Replacement Therapy (HRT), specifically estrogen therapy (ET) and progesterone hormone therapy (HT) formerly the most commonly recommended course of action in preventing bone loss, is now one of the least recommended. This is due in part to an increased risk for breast and endometrial cancer with long term usage (defined as five years or more). In 2002, the Women's Health Initiative in conjunction with the National Institute of Health announced that the use of Prempro (an HRT), coincided with an increased occurrence of breast cancer, heart attacks and strokes (Rossouw JE, Anderson GL, Prentice RL (2002). Currently, Selective Estrogen Receptor Modulators (SERMS), which are estrogen agonists/ antagonists medications, are more commonly recommended and are for the prevention and treatment of osteoporosis in postmenopausal women.

Antiresorptive Medications, or Bisphosphonates, come in various forms that are commonly advertised in women's magazines including Fosamax®, Boniva®, Actonel®, Reclast®, Fortical®, and Miacalcin®. The Actonel® is the only one recommended for osteoporosis in both men and women as a long term side effect of steroid use (like glucocorticoids). Bisphosphonates work by preventing osteoclasts (the bone destroying cells) from digesting bone. Osteoclasts participate in the resorption part of bone turnover

by removing the mineralized matrix and breaking up the organic bone collagen. These cells can also destroy themselves in what is called “cell suicide” or poor apoptosis. Bisphosphonates encourage apoptosis to occur. They have been around since the 19thc but were first seriously used in the 1960’s preliminarily as a water softener in orange groves. It is estimated that 50% of bisphosphonate is excreted by the kidneys unchanged while the remaining 50% are quickly absorbed by bone tissue. Some of their side effects include stomach upset and inflammation and potentially erosion of the esophagus, flu like symptoms, and occasionally renal failure and atrial fibrillation. (Weinstein, R., Roberson, P., Manolagas, Stavros C. and Giant 2009), (Drake, M., Clarke, B. and Kholsa, S., 2008), (NOF, 2008).

The last class of medications is the bone forming (anabolic) medication, called Teriparatide (brand name Forteo), a type of parathyroid hormone. This is recommended for postmenopausal women and men with very low bone mass, or those at high risk for fracture. Although currently the FDA recommends that individuals only take these medications for two years. It is still under investigation because of a potential side effect of an increased risk of osteosarcoma (bone cancer). The parathyroid hormone is the primary regulator of calcium and phosphate metabolism in bone and kidneys. The drug works to activate osteoblasts to build more bone, however too much of this drug can cause the opposite effect. It is the first FDA approved drug that actually causes new bone formation (Saag, K., Shane, E., Boonen, S., Marin, F., Donley, et al., 2007); (NOF, 2008).

Can Weight Bearing Exercise increase Bone Mass? Protocols for Strength Training.

All signs point to yes. In a review of 20 articles regarding weight training and osteoporosis, researchers determined that there was true evidence to support the effectiveness of weight training in postmenopausal women. The research showed that the increases in BMD were site-specific, and required high loading with a training intensity of 70 – 90% of 1RM (repetition maximum) for 8 to 12 repetitions of 2 – 3 sets performed over one year duration. However, once begun an exercise program must be a lifelong change because bone loss is chronic. (Zehnacker, CH, Doughter, B., 2001, 2007). In the *Journal of Orthopedic medicine*, a one year study of brisk walking and gymnastic training among 35 postmenopausal women with osteoporosis displayed a significant increase in lumbar bone mass density. But interestingly, they also discovered that within 2 years the bone mass density reverted back to a level similar to the control group (who never exercised at all). This demonstrates that in order to increase bone mass density, one's exercise training program should not be stopped (Iwamoto, J., Takeda, T., Ichimura, S., 2001).

According to the National Osteoporosis Foundation, exercise, such as weight bearing walking, running, etc, stimulate bones to retain calcium and produce more bone mass. But swimming, which is not weight bearing, does nothing to increase bone density. The downside, of course, is that for an individual that has already suffered bone loss the risk of stress fractures in the vertebrae, hips and other regions may be increased. Running, walking and the like may further complicate issues and do not provide strengthening to the upper body. Also if you exercise too much, and lose too much body

fat you actually increase your chances for developing osteoporosis, according to the National Osteoporosis Foundation (NOF, 2008).

The International Osteoporosis Foundation has recommendations for health professionals working with postmenopausal women on its website. The IOF believes and recommends the protocols set by the Kemmler study in 2004 and supports the findings. The Kemmler study focused on high impact strength and endurance training in postmenopausal osteopenic women. It was conducted over two years, and consisted of 4 training sessions a week (two in home, two in gym setting). The strength training group showed a significant increase in lumbar BMD but not hip BMD. The exercise group also had significant changes in isometric strength and increased VO₂ max. Both these indices decreased over the two years in the control group (Kemmler W, Engelke K, Weineck J, Hensen J, Kalender W, 2003).

The protocol for an osteoporosis program according to the IOF is as follows: Four sessions per week 2 in an exercise facility for 60 – 70 minutes, and two at home for 25 minutes. The sessions are a combination of cardiovascular work and strength training.

Cardiovascular Training Protocol:

First 3 mos: walking/ running for up to 20minutes

After 3 mos: 10 minutes of low to high impact cardiovascular exercises eventually resulting in high impact exercises towards the end of the session.

After 6 mos: Jumping sequences can be introduced except in the case of vertebral fractures, where walking is recommended. Rope skipping can be introduced beginning with single leg movements and

eventually working towards more complicated movements that involve rope jumping with the legs together.

Strength Training Protocol: The IOF recommends two sessions per week in an exercise facility, one involving resistance machines, and the other isometric exercises utilizing elastic belts, dumbbells, weighted vests. Participants are also expected to do 25 minutes of isometric exercises at home, and can eventually add in rope skipping after 20 weeks in the program.

Resistance Machines:

First 3 mos – 2 sets of 20 reps at 50% of 1RM

3 – 5mos – 2 sets of 15 reps at 60% of 1RM

5mos – 2 sets of 15 reps at 65% of 1RM

7mos – 70 – 80% of 1RM

Isometric Exercises

First 7mos – 3 exercise belt exercises of 15 – 20 reps, as well as isometric exercises using bands focused on the trunk and legs.

After 7mos – the belt is replaced by a dumbbell and free weights.

In addition, the IOF recommends balance training to help prevent falls. Tai Chi, or other kinds of balance training are recommended. Specific recommendations include a 10 – 15 minute warm up and then onto a workout geared around balance and gait, as well as heel raises, tandem walks, and obstacle courses.

There are also exercises that are contraindicated for individuals with osteoporosis by the IOF. Any kind of dynamic abdominal exercises like sit ups or things that involve

extreme flexion can cause damage to the spine through the strong pressure they exert.

Also, twisting motions, high impact and abrupt movements are contraindicated.

(Pfeifer, M., Minne, H., n.d). It should be noted that in this study and in many other studies many of the subjects were supplemented with Calcium and vitamin D (Kemmler, et. al, 2003), (Iwamoto, et al. 2001).

Will Pilates Increase Bone Density?

There has been very little research in this area of the fitness field. It seems that several, though not many scientific studies have been done on the efficiency of Pilates in prevention of lower back pain, there have been few done in relation to osteoporosis. In all cases reviewed, the outcome has been positive (Leger, A 2006), (Da Fonseca, M., Magini M, de Freitas T., 2009). Pilates reduces back pain, but there has been little to no research in regards to osteoporosis. There have been a few books written, which I am currently reviewing. Pilates is a full body, weight bearing, low impact workout that holds a lot of promise for individuals with osteoporosis if modified properly.

Pilates Mat Exercises

The mat exercises offer both some positive (and negative aspects in relation to osteoporosis. Because the exercises are all performed on the floor it makes them easy to perform for individuals with balance challenges. However, the majority of Pilates exercises involve flexion to the spine, which can be contraindicated for osteoporosis, especially in the case of spinal fractures. The power it takes to perform some of the exercises, may also cause excessive strain on the spine. I believe that these obstacles can

be overcome, by adjusting the postures to standing postures using a ballet barre, and by using resistance bands as additional support for exercises that require power.

Pilates Reformer Exercises

A Reformer program of exercises appropriate for individuals with osteoporosis, is much easier to design than a mat program, because there are a vast amount of reformer exercises. However, the challenge is in how the machines are weighted. Each Pilates machines has slightly different springs from vendor to vendor. Only general recommendations can be made for each exercise. The best way to overcome this, is to rate the exercises on a RPE or rate of perceived exertion scale. Initially exercises should not be above a 4 or 5 RPE, but towards the end of the year can be around a 7 or 8 RPE.

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