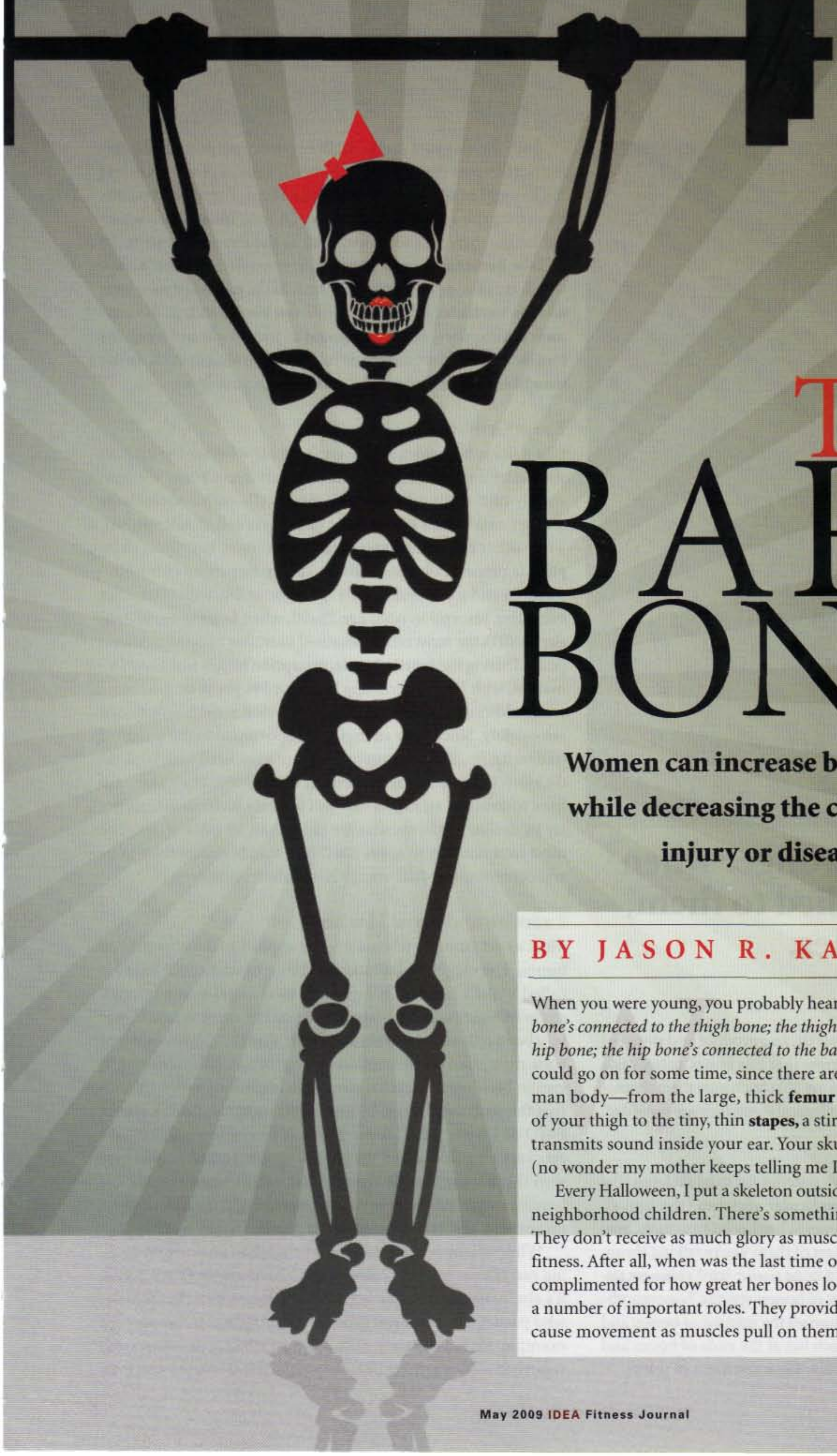


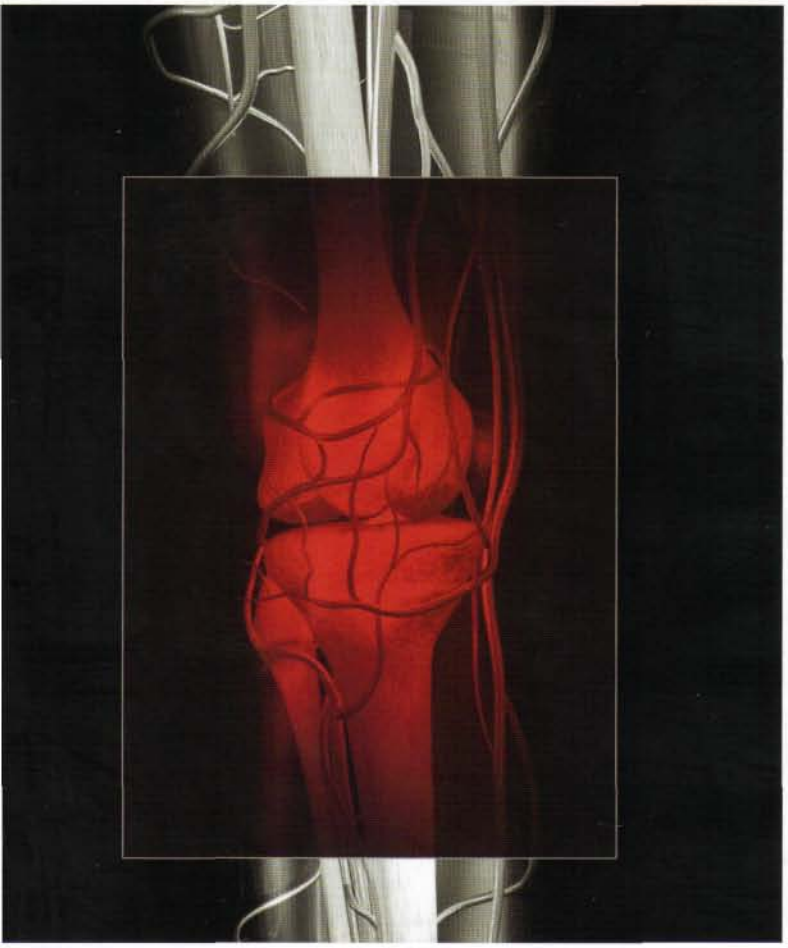
THE BARE BONES

Women can increase bone health while decreasing the chances for injury or disease.

BY JASON R. KARP, PHD

When you were young, you probably heard the jingle *"The knee bone's connected to the thigh bone; the thigh bone's connected to the hip bone; the hip bone's connected to the back bone . . ."* That ditty could go on for some time, since there are 206 bones in the human body—from the large, thick **femur** that spans the length of your thigh to the tiny, thin **stapes,** a stirrup-shaped bone that transmits sound inside your ear. Your skull alone has 22 bones (no wonder my mother keeps telling me I have a hard head!).

Every Halloween, I put a skeleton outside my door to scare the neighborhood children. There's something scary about bones. They don't receive as much glory as muscles, the poster kids for fitness. After all, when was the last time one of your clients was complimented for how great her bones looked? But bones serve a number of important roles. They provide shape to our bodies, cause movement as muscles pull on them, support and protect



Muscles get stronger when a stress is applied to them, and so do bones.

internal organs, store fat and minerals, and produce and store red and white blood cells in the marrow that fills bones' many cavities. And, just like muscles, bones are able to change their characteristics based on the amount of physical stress they are provided.

Bone Architecture

Our skeletons are divided into two systems: the **axial skeleton** (the head and trunk) and the **appendicular skeleton** (the limbs). Although most people think of bones as hard, solid structures, how solid they are depends on what part of them you're talking about. There are three different kinds of bone tissue: hard **compact tissue,** which comprises the exterior of bones; spongy, honeycomb-like **cancellous tissue,** which comprises the interior of bones; and smooth **subchondral tissue,** which lies at the ends of bones and is covered with cartilage to cushion the movement of joints.

Both the compact and cancellous tissues are porous; the difference between the two tissues is merely the size of the pores and the amount of solid material between them. Together, these tissues comprise four different kinds of bones: **long bones,** which are longer than they are wide, such as the femur in your thigh and the **humerus** in your upper arm; cube-shaped **short bones,** which are as wide as they are tall, such as the **patella** in your knee and the **navicular** in your foot; thin **flat bones,** such as the **sternum** in your chest and the **occipital** in your skull; and **irregular bones,** which don't conform to a specific shape, such as the **mandible** in your jaw and the **vertebrae** in your spine.

Bone Growth

Like a fickle homeowner who can't decide whether the kitchen should be done in English country or art deco, bones are constantly remodeling themselves. Bone cells called **osteoclasts** remove small areas of old bone (a process called **resorption**), while other cells called **osteoblasts** synthesize new bone in its place (a process called **formation**). This cyclic process of bone resorption and formation occurs throughout life, with formation exceeding resorption until age 25–30, when **bone mineral density (BMD),** the most often measured indicator of bone strength, peaks. During the fourth decade, resorption begins to exceed formation, with BMD decreasing by about 1% per year.

In addition to age, nutrition and physical activity affect bone remodeling. Since bone strength is proportional to the square of its density, small reductions in BMD are associated with large reductions in bone strength (Bennell et al. 1999). Therefore, you need to consider strategies that will increase BMD or at least delay its decline in clients who are older than 30 years of age. The most common way to assess BMD is to scan bones for their mineral content using dual-energy X-ray absorptiometry.

Exercise and Bone Health

Muscles get stronger when a stress is applied to them, and so do bones. The elegant adaptation of bone to withstand stress is called Wolff's Law and is explained by changes to the internal strain of bone caused by external stress. The stress activates mature bone cells called **osteocytes,** which alter the balance between bone resorption and formation in favor of formation, leading to greater bone mass. External stress is so important to bone health that the absence of stress by immobilization results in losses in BMD of 1% per week (Borer 2005). If you or your clients have ever kept a leg elevated off the ground by using crutches, you have seen the massive muscle atrophy that occurs when you are not bearing weight on the injured leg. Interestingly, the lack of stress on your leg affects the bones just as much.

While weight-bearing exercise is better than non-weight-bearing exercise for burning calories and losing weight (Karp 2008), it's also better for your bones. Research has shown that females who participate in sports involving running and jumping—for example, soccer, distance running, basketball, gymnastics and volleyball—have greater BMD than nonactive women and even than female athletes who participate in nonimpact sports, such as swimming, cycling, cross-country skiing and rowing (Borer 2005). However, while athletes in weight-bearing sports have greater BMD, it's hard to say that exercise is its cause, since it's possible that people with genetically denser bones are more likely to participate and succeed in sports that are stressful on the skeleton. More longitudinal research needs to be done to determine the effect of participation in weight-bearing sports on BMD.

While *some* running is good for bones, *more* running is not necessarily better. In a cross-sectional study, MacDougall and colleagues (1992) found that a group of male runners who ran 15–20 miles per week had significantly greater BMD in the tibia and fibula than both a control group of sedentary males and a group who ran 5–10 miles per week. Interestingly, with running mileage greater than 20 miles per week, BMD showed no further increase and actually tended to decrease, such that for the group who ran the most (60–75 miles per week), BMD was similar to that of the nonrunning control group. However, as BMD decreased with more running, the width of the tibia and fibula tended to increase—in those who ran 40–55 miles per week it was significantly greater than in the control group. This may represent a positive adaptation aimed at reducing tension on the bones (compression force per unit area), thus protecting them from injury.

Cross-sectional research examining the effects of different amounts of running on BMD in women has also shown a negative association between running mileage and BMD; however, this issue is complicated in women by the negative effect of training volume on menstruation and associated estrogen levels, which itself affects BMD (Cobb et al. 2003). In a cross-sectional study on female distance runners aged 18–44 years, Burrows and others (2003) found slightly negative correlations between lumbar-spine and femoral-neck BMDs and weekly running distance. Specifically, runners who ran 10 kilometers (6.2 miles) per week more than other runners had a 1% lower lumbar-spine BMD and a 2% lower femoral-neck BMD. In a longitudinal study, Bemben et al. (2004) found that BMD of the lumbar spine and proximal femur of female college cross-country runners tended to decrease (at a practically significant level) over a 6-month training period during which they ran more than 40 miles per week.

Comparing athletes in different sports, a number of studies have found that those engaged in high-impact activities have the highest levels of BMD. Taaffe and colleagues (1997), who monitored changes in BMD in the lumbar spine and femoral neck among gymnasts (who regularly experience high-impact loads equaling 10–12 times body weight on landing), distance runners and swimmers for 8–12 months, found that the percent change in BMD at both sites was significantly greater in the gymnasts than in the runners and swimmers, despite the fact that the gymnasts had a higher BMD at the beginning of the study. Bemben and others (2004) also found that gymnasts had greater lumbar-spine, proximal-femur and total-body BMD values than cross-country runners, both at the beginning of the study and after 6 months of training.

Despite the repetitive stress of running (which imposes two to three times the person's body weight with each footfall), weight training, with its high forces, has an even greater impact on BMD (Layne & Nelson 1999). Female weightlifters have a greater BMD than athletes in other sports, including orienteering, cross-country skiing, cycling, running and swimming (Heinonen et al. 1996; Heinrich et al. 1990). Davee, Rosen and Adler (1990) found that women who combined aerobic exercise and weight training had a greater BMD of the lumbar spine than women who did only aerobic exercise. A number of other studies have also shown that weight training increases BMD, especially in premenopausal

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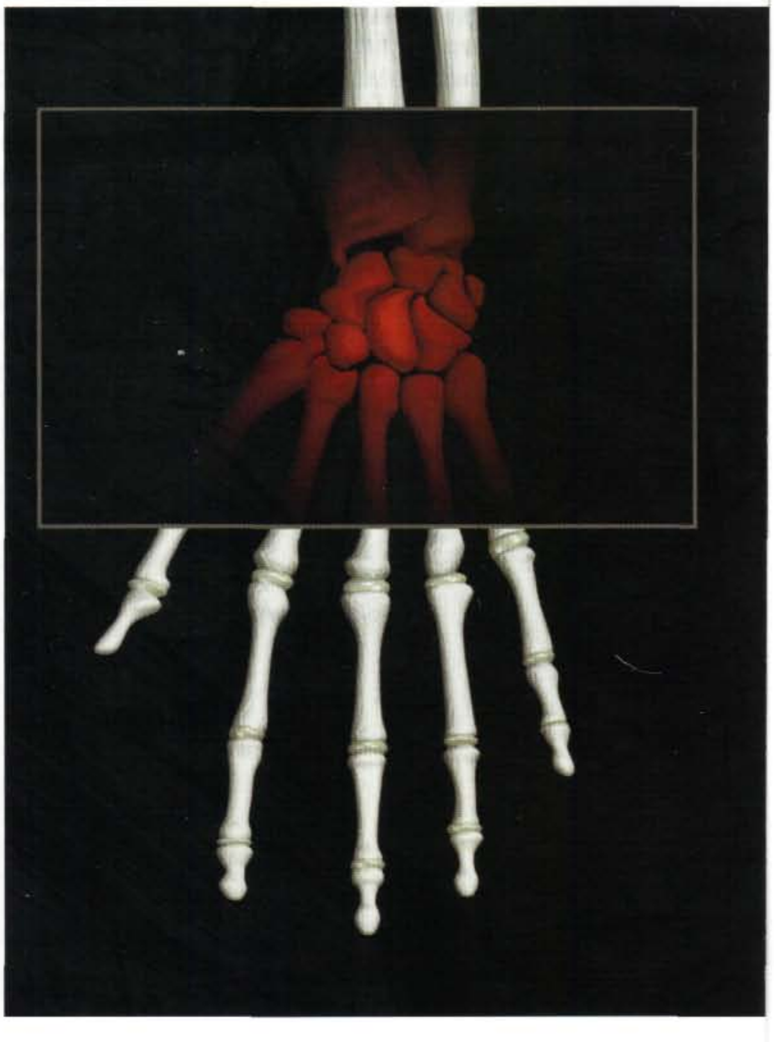
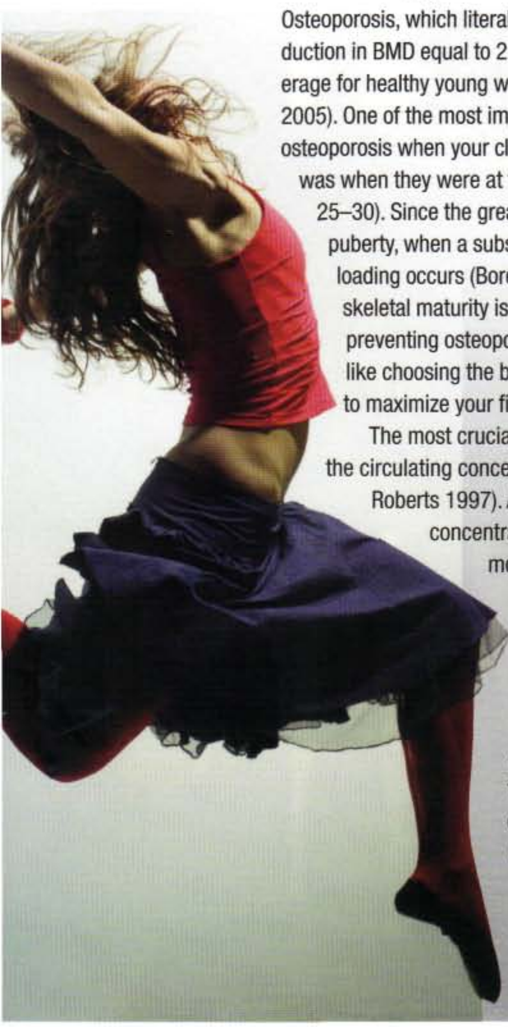


women (Layne & Nelson 1999; Petranick & Berg 1997). The strong contraction of muscles as they pull on the bones to which they attach influences the magnitude of stress on the bones themselves.

In a clever study in which the subjects served as their own controls, Haapasalo and colleagues (1996) discovered that tennis players have a greater BMD in their playing arms compared with their nonplaying arms. Since one would not expect the bones of one arm to be denser than the bones of the other arm of the same person, this finding suggests that the effect of forceful muscle contractions alone is enough to increase BMD. Since the magnitude of the stress on the bone is more important for increasing BMD than the number of times the stress is repeated (Prior et al. 1996), your clients need only one set with a heavy weight to increase BMD. In addition, weight training should target specific body parts, since the effect of weight training on BMD is specific to the bones that attach to the muscles being used.

While many studies have shown statistically significant increases in BMD in both pre- and postmenopausal women in response to weight-bearing exercise and strength training, it is important to note that the magnitude of increase in BMD is only 1%–2% (Borer 2005; Karlsson 2004; Layne & Nelson 1999; Taaffe et al. 1997). Some studies have even found that strength training has no significant effect on BMD (Heinonen et al. 1996; Layne & Nelson 1999). Is there any clinical significance to a BMD increase of just 1%–2%? While research suggests that exercise is associated with a reduced risk of falls in the elderly and a reduced bone fracture risk (Karlsson 2004; Prior et al. 1996), it is difficult to determine whether that reduced risk is a consequence of increased BMD in people who exercise. For example, the reduced risk of falls and fractures could also result from exercise-induced increases in muscle strength and endurance, coordination, balance, posture and flexibility.

Osteoporosis



Osteoporosis, which literally means "porous bones," is a reduction in BMD equal to 2.5 standard deviations below the average for healthy young women at the age of peak BMD (Borer 2005). One of the most important determinants in preventing osteoporosis when your clients are older is what their BMD was when they were at the age of their peak BMD (age 25–30). Since the greatest impact on BMD occurs before puberty, when a substantial exposure to mechanical loading occurs (Borer 2005), exercising before reaching skeletal maturity is paramount for maximizing BMD and preventing osteoporosis. Exercising before puberty is like choosing the best 401(k) plan when you're young to maximize your financial status upon retirement.

The most crucial determinant of BMD in women is the circulating concentration of estrogen (Robergs & Roberts 1997). Any condition that reduces estrogen concentration negatively affects bone remodeling, which explains why a woman's risk for osteoporosis and fractures increases dramatically with amenorrhea and after menopause, when there is a lack of estrogen. Indeed, estrogen deficiency caused by amenorrhea is the most significant risk factor for osteoporosis in active women. A number of studies have found a significant loss in BMD, particularly at the lumbar spine, in amenorrheic athletes (Borer 2005).

To compensate for the decrease in estrogen that accompanies menopause, many postmenopausal women begin estrogen replacement therapy (ERT) to prevent osteoporosis and bone fractures. ERT inhibits the formation and function of osteoclasts, thus hindering bone resorption, and prolongs the lifespan of osteoblasts—effects which together increase bone density. While many studies have shown an increased BMD and a decreased risk of fractures with ERT, receiving supplemental estrogen is not without its own risks, as ERT has been linked to an increased risk for breast cancer and cardiovascular disease (Delaney 2006). If you work with postmenopausal women, it is important that they be screened for osteoporosis, breast cancer and cardiovascular risks so that the cost-to-benefit ratio of ERT can be determined.

While supplemental estrogen from ERT increases bone density in postmenopausal women, research on supplemental estrogen provided by birth control medication has shown mixed results. Oral contraceptive use has been found to have no effect on BMD (Lloyd et al. 2000; Liu & Lebrun 2006); to increase BMD (Cromer et al. 2008; Gambacciani et al. 2004); and even to decrease BMD, especially when the contraceptives are taken during late adolescence or early adulthood (Shoepe & Snow 2005; Weaver et al. 2001). It seems that oral contraceptive use may cause an increase in BMD only if taken at the onset of menopause. In premenopausal women with normal menstrual cycle activity, oral contraceptive use does not appear to benefit bones (Gambacciani et al. 2004; Liu & Lebrun 2006). To be safe, your clients should consult with their gynecologists before taking oral contraceptives.

Strategies to Increase Bone Mineral Density and Maintain Bone Health

Exercise

- high-intensity resistance exercise
- resistance exercise that focuses on the muscles of the lumbar spine and anterior/posterior hip regions
- plyometric exercises (box jumps, depth jumps, leg bounding, etc.)
- an emphasis on movement in varying directions
- weight-bearing exercise during adolescence, before skeletal maturity is reached

Nutrition

- 1,000 mg of calcium per day for women aged 19–50 years; 1,200 mg per day for women over 50 years
- 400 IU of vitamin D per day for women aged 19–50 years; 600-800 IU per day for women over 50 years
- adequate caloric intake to meet metabolic needs

For bones to maximize their adaptive response to exercise, they require a dynamic, rather than static, stress; either a low-frequency, high-intensity stimulus (e.g., heavy weight training with few reps per set) or a high-frequency, low-intensity stimulus (e.g., running 5 miles at an easy pace), with a high-intensity stimulus being more effective; and a direction and magnitude of stress different from what are normally experienced (Borer 2005; Prior et al. 1996).

Bone Injuries

As is the case with muscles, tendons and ligaments, too much stress on bones can cause injuries. The irony is that, even though the extra stress associated with weight-bearing exercise increases BMD, that extra stress also increases the chance of bone injury. One of the most common bone injuries, especially for people new to a weight-bearing exercise like running, is **shin splints** (medial tibial stress syndrome). As the medical name implies, pain is felt along the medial (inner) border of the tibia, and it feels as though someone has kicked you—repeatedly. Shin splints are caused either by excessive ankle **pronation** during running (an inward roll of the foot immediately following landing on the ground) or by exposure to excessive shock to which the bone is initially unable to adapt.

Another common and more serious bone injury is a **stress fracture,** which contrary to the dull, poorly localized pain of shin splints, is characterized by a sudden, sharp pain at a specific point on the bone. Stress fractures occur when there is an abnormal concentration of stress at a particular site in the bone and the bone is not strong enough to resist that stress. Despite all of the medical issues associated with obesity, there is some good news for obese women: they have a lower risk for bone fractures than normal-weight or lean women, since body fat protects bone mass (Borer 2005).

Women seem to have a greater risk for stress fractures than do men, especially if the women have one or more of three associated characteristics—menstrual irregularities, disordered eating and osteoporosis—collectively called the **female athlete triad.** High training volumes can cause irregular or even absent menstrual cycles (amenorrhea), both of which increase the risk for osteoporosis and stress fractures, since active women with irregular menstruation or amenorrhea have lower BMD than women with normal menstruation (Cobb et al. 2003).

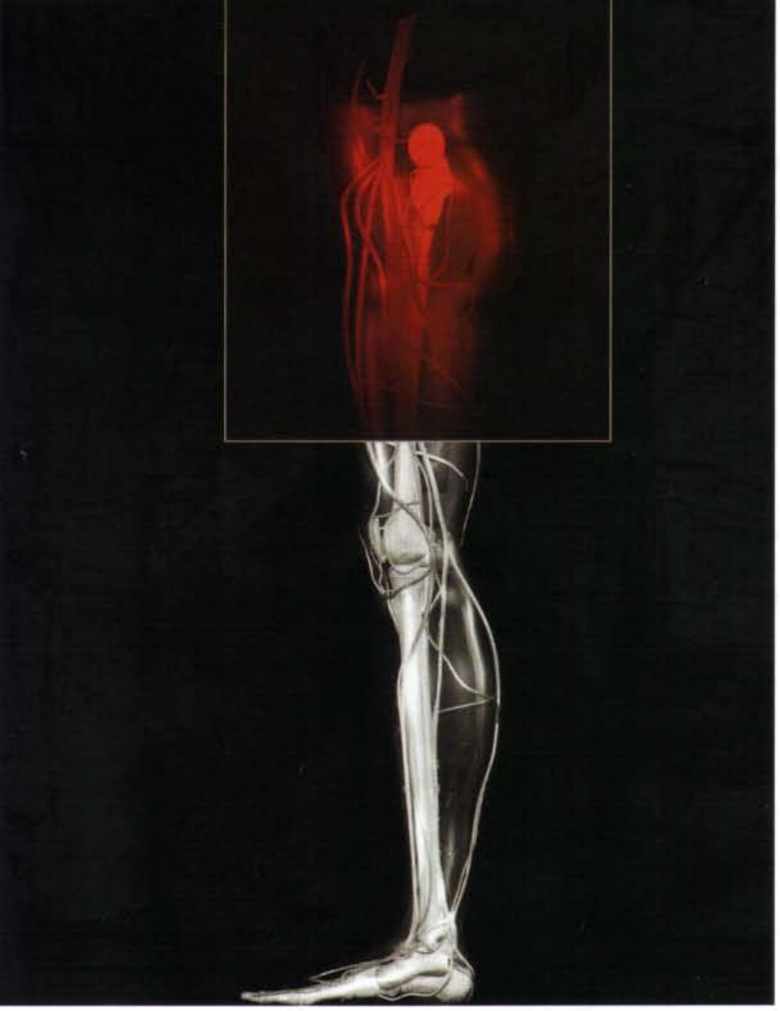
Disordered eating (not to be confused with an eating disorder like anorexia or bulimia) can also affect BMD. Common among active women, owing to external or self-imposed pressures to lose weight, disordered eating may result in caloric restriction and is independently associated with both irregular menstruation and low BMD (Cobb et al. 2003). Many amenorrheic women have a diet low in calories and are therefore not meeting their needs for specific nutrients, such as calcium and vitamin D. On the other hand, a client can have normal menstruation and still have low BMD if her dietary habits do not meet her caloric needs. If clients have any of the characteristics of the female athlete triad, they should regularly have their BMD assessed.

Nutrition and Bone Health

While weight loss in the United States is still often sought through dieting, bone mass loss is also associated with dieting. For every kilogram of fat lost, about 16.5 grams of bone mineral are lost as well (Borer 2005). To increase their density, bones need an abundant amount of nutrient energy. Thus, dieting is not the answer.

Two essential nutrients for bone health are calcium and vitamin D. Calcium directly increases bone formation by being deposited into bones, while vitamin D does so indirectly by increasing intestinal calcium absorption and by increasing bone resorption to provide calcium from "old" bone to make "new" bone. Many women do not absorb enough calcium (owing to lack of estrogen and low vitamin D intake), thus limiting the effectiveness of exercise. Vitamin D is available in many fortified dairy products, and our bodies also synthesize vitamin D upon skin exposure to sunlight. Another important nutrient for bones is vitamin K, which is contained in green, leafy vegetables. Aside from its important role in blood clotting, vitamin K assists in the synthesis of **osteocalcin,** a bone protein that attracts calcium.

While bones are the body's largest storage site for calcium (Petranick & Berg 1997), this mineral also exists in the blood. Blood calcium level is regulated by parathyroid hormone, which



is produced by the parathyroid glands. When blood calcium decreases, production of parathyroid hormone increases and stimulates bone resorption so calcium is released into the blood. That's why dietary calcium is so important—if it's insufficient, calcium will be "stolen" from bone to maintain its level in the blood. So encourage your clients to forgo that midafternoon soda from the vending machine outside their office—and urge them instead to drink some milk, even the chocolate variety!

The Institute of Medicine of the National Academy of Sciences advises that women aged 19–50 years need to consume 1,000 milligrams (mg) of calcium and 400 International Units (IU) of vitamin D per day and women over 50 years (or postmenopausal) need to consume 1,200 mg of calcium and 600–800 IU of vitamin D per day (Borer 2005). There is no evidence that active women need to consume more than these values. However, the average intakes of both calcium and vitamin D for North American Caucasian women fall far short of these recommendations, with women aged 19–50 years consuming 74% and women over 50 years consuming only 55% of the recommended daily amounts (Borer 2005).

Adequate calcium and vitamin D intakes become increasingly important after age 40, when losses of bone mineral become measurable (Borer 2005). While dietary sources of calcium and vitamin D are optimal, your clients should consider supplements if their diets alone cannot provide the recommended daily intake. Most research on the effect of calcium supplementation on BMD in middle-aged women has reported positive results (Borer 2005). Women who want to determine whether a supplement is appropriate for them must look at factors such as diet, menstrual cycle and current bone density.

So if your clients want strong, dense bones, increase the strain on their bones with both weight-bearing and high-intensity resistance exercises and tell clients to consume adequate amounts of calcium and vitamin D, especially as they get older. If they train hard enough, they'll surely have the strongest bones of all their friends, strong enough even to scare the Halloween skeleton outside my front door! ■

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