Designing Resistance Training Programs by Steven Fleck, William Kraemer

Children and Resistance Tra

After studying this chapter, you should be able to

1. outline training adaptations in preadolescents and adolescents,
2. discuss acute and chronic injuries due to training in preadolescents and
3. describe the steps in developing a safe, effective weight training progra lescents and adolescents,
4. describe resistance training program differences in children of varying ag
5. develop a periodized resistance training program for preadolescents and ado
6. describe equipment modifications that may be needed when children perfo training, including appropriate resistance increases during the program.

The popularity of resistance training among prepubescents and adolescents has increased dramatically. The acceptance of youth resistance training by qualified professional organizations is becoming universal. The following organizations have produced statements indicating that youth resistance training is both effective and safe when properly supervised: American Academy of Pediatrics (2008), American College of Sports

growth spurt) and females (pri ation)? What type of weight t appropriate for a pubescent, ar program differ from a prepu How can resistance training be youth? All of these questions h on research. However, some m misunderstandings still exist.

When evaluating informatio

BOX 10.1 RESEARCH

Puberty and Maximal Strength Gains

It is generally believed, and some research supports this belief, that during puberty m significantly increases. However, this does not mean that resistance training of postp results in greater strength gains than training of prepubertal children. A meta-an that the maturity of both prepubertal and postpubertal children significantly affect as a result of weight training (Behringer et al. 2010). However, there is no signific strength gains due to resistance training during puberty compared to prepuberty This meta-analysis also concluded that longer-duration studies and increased trai significantly affect strength gains. The conclusion that longer-duration studies r strength gains indirectly supports the belief that hypertrophy contributes to strength Although the conclusion that increased frequency (e.g., two or three sessions per w for strength gains, the meta-analysis also showed that strength increases are related

BOX 10.2 PRACTICAL QUESTION

To Cause Muscle Hypertrophy, Does the Resista Training Program Need to Be Unique?

Weight training programs do not need to be unique to bring about significant hyp dren. For example, overweight children (pretraining BMI of 32.5) performing eight training with 10 machine exercises for two circuits of eight repetitions per exercise, 70% of 1RM and progressing to 90% of 1RM, with one minute of rest between e a significant increase in total lean body mass of 2% (Naylor, Watts et al. 2008). T significantly greater than the change shown in a group of nonexercising childre performing weight training showed a nonsignificant decrease in fat mass. The co increase in total lean body mass and decrease in fat mass resulted in a significant de body fat of 1% (49.6 to 48.5%). Programs used in other studies showing a signifi lean body mass are also not unique from a program design perspective.

BOX 10.3 RESEARCH

Motor Performance Improvements as a Child's Age In

Changes in mean motor performance of adolescent soccer players indicate that spr improves in the early teenage years, whereas vertical jump performance improves at rate throughout the teenage years (Williams, Oliver, and Faulkner 2010). It is impo this information is longitudinal, and not cross-sectional, which makes it more r of improvement from year to year. Even though mean changes can be calculated, variations in motor performance test improvements do exist. The total percentage in the 10 m sprint, 30 m sprint, and vertical jump from under 12 years to under 15, and 28%, respectively (see table 10.2).

TABLE 10.2 **Motor Performance Changes From 12 to 16 Years of Age**

Age (years)	Mean 10 m sprint (sec)	10 m sprint % improvement from previous year	Mean 30 m sprint (sec)	30 m sprint % improvement from previous year	Vertical jump (cm)
Under 12	1.98	—	5.04	—	44.9
Under 13	1.97	0	4.97	1	47.9

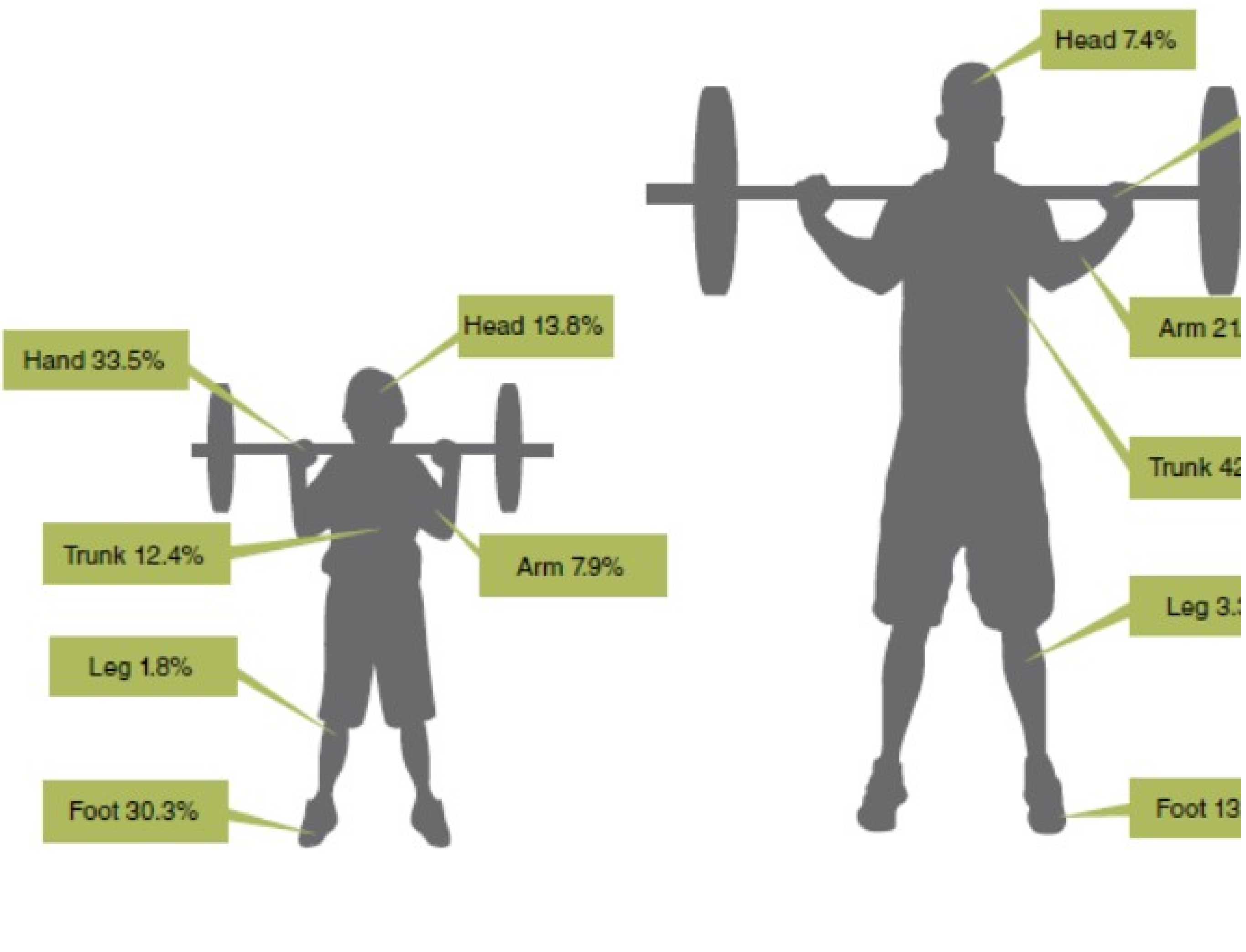
sport-specific motor performance in preadolescents and adolescents.

Bone Development

Resistance training can have a favorable effect on bone mineral density in prepubescents and adolescents of both sexes (National Strength and Conditioning Association 2009; Naughton et al. 2000). Moreover, weight training has no detrimental effect on linear growth in children and adolescents (National Strength and Conditioning Association 2009; Malina 2006). However, not all studies report an effect on bone mineral density in children. It has been hypothesized that mechanical loading of bone has a threshold that must be met to have a positive effect on factors related to bone health, such as bone mineral density (Twisk 2001). Thus, studies that report no effect on bone mineral density as a result of resistance training may not have reached the threshold of mechanical

Unfortunately, the minimal r
necessary to bring about chan
is not known.

Increased bone density fro
ing may be one of the primar
involved in empirical observat
training prevents injury in you
et al. 1982). Prepubescence an
be an opportune time to incr
density and periosteal expansi
(compact bone) through phy
2000; Khan et al. 2000; Nati
Conditioning Association 2009
ant consideration for long-t
because training increases i
lost over time when physical a
(National Strength and Condi
2009). Athletes who increase b
in adolescence appear to suff
later years despite reduced phy
et al. 2000; Nordstrom, Olssc



Muscle Strains and Sprains

Muscle strains and sprains are common injuries in all age groups (Meyer et al. 2009). Strains and sprains account for 18, 44, 60, and 66% of all injuries in 8- to 13-, 14- to 18-, 19- to 22-, and 23- to 30-year-olds (Meyer et al. 2009). The risk of sprains and strains significantly increases with increasing age. Strains and sprains can be the result of not warming up properly before a training session. Trainees should perform several sets of exercise before beginning the actual training sets of a workout. Other common causes of muscle strain or sprain are attempting to lift too much weight for a given number of repetitions and improper exercise technique. Children should understand that the suggested number of repetitions is merely a guideline, and that they can perform fewer repetitions than prescribed in the training program. The incidence of this type of injury, as with all injury types, can be reduced by taking proper safety precautions.

Growth Cartilage Damage

Growth cartilage damage is historically a traditional concern for children performing weight

long bones of the body grow epiphyseal plates. Damage to t but not to the other types of g decrease linear bone growth. of hormonal changes, the epi after puberty. Once this hap long bones, and therefore inc longer possible.

The epiphyseal plate is weal rapid growth during pubesce and Maffulli 2006). Addition ization may lag behind linear bone more susceptible to inj and Maffuli 2006). The cartil acts as a shock absorber betw form a joint. Damage to this to a rough articular surface a during joint movement. The apophyseal insertions of majo solid connection between th Damage to apophyseal inserti and also increase the chance o the tendon and bone, result fracture. It has also been pr the growth spurt muscle tend

BOX 10.4 **PRACTICAL QUESTION**

What Are Recommendations for a Beginning Resis Training Program for Adolescents?

Weight training program recommendations for a beginning adolescent lifter inclu (Miller, Cheathman, and Patel 2010):

- Primary training goal: increase strength
- Number of sets: one to three
- Repetitions per set: 10-15, depending on previous weight training experien
- Resistance: one that allows the performance of the desired number of repet
- Training frequency: two or three sessions per week on nonconsecutive days
- Exercises: involve all the major muscle groups—chin-up, bench press, lat press, knee flexion, knee extension, abdominal crunch, biceps curl, tricep

TABLE 10.6 **Resistance Training Workout for Children Using Body We and Self-Resistance**

Exercise	Sets × repetitions
Push-up	1-3 × 10-20
Bent-leg sit-up	1-3 × 15-20
Parallel squat	1-3 × 10-20
Self-resistance arm curl using opposite arm as resistance	1-3 × 10 actions 6 sec in duration
Toe raise	1-3 × 20-30

resisted exercises, fit is typically not a concern. With resistance training weight machines, however, fit can be critical. Although several companies now manufacture machines specifically for children, most resistance training machines are designed to fit adults (see figure 10.7). Most prepubescents lack the height and arm and leg length to properly fit many adult resistance training machines. If the machine does not fit the child properly, correct technique and full exercise range of motion are impossible. A critical danger of an ill-fitting machine is that a body part such as a foot or an arm may slip off its point of contact, resulting in injury.

Another common fit problem is a bench for machine or free weight exercises that is too wide to allow free movement of the shoulder during the exercise. When children perform exercises with inappropriate technique because of ill-fitting equipment, their joints and musculature can be exposed to undue stress, resulting in an injury.

Children should not use equipment that cannot be safely adapted to fit properly. Simple alterations of some machines, such as additional seat pads, can allow a trainee to use the machine safely. However, just adjusting the seat is often not enough. Although the seat adjustment may be appropriate, adjustments may also be needed to allow proper positioning of the arms or legs on the contact points of the machine. In addition, raising the seat may make it impossible for the child's feet to reach the floor, compromising balance. Placing blocks under the feet can help in such cases.

Altering a piece of equipment to fit one child does not guarantee that the equipment will fit another child. Proper fit must be checked before the equipment is used by each child. Care must be taken to ensure that additional padding or blocks do not slide during the exercise, which could result in injury. Sliding can be avoided in some alterations by attaching nonskid material to the top and bottom of blocks and the backs of additional

especially important when b
dren are training in the same f
philosophy can be promote
ways:

- Posting age-related in dren next to the adul can include both pro instructions.
- Using posters and pict pubescents and adoles using proper resistance
- Using charts, contests, mote the principles on v and adolescents need f for training consistency total conditioning and other aspects of total fi endurance), and prep and within a sports sea

The environment, exerci awards should all reflect the p Because prepubescents and a retain information in different the weight training program s the expectations and philoso communication, including c video, and pictorial media. A nication need to be clear and pubescents and adolescents s confusion, or misunderstandi any aspect of the program.

Summa

Resistance training for prepu lescents has gained accepta because strength, power, and h can occur, bone developmen and injuries may be prevented ities with developmentally ap

Resistance Training for Se

After studying this chapter, you should be able to

1. distinguish between modifiable and non-modifiable factors as they relat population,
2. describe the hormonal changes of aging men and women with respect to and menopause and the overall implications relative to the senior popul
3. list the changes in body composition associated with aging and the i cumulative impacts,
4. explain the phenomenon of muscular strength and power loss seen, a

Those who design programs for senior popula- tions need to understand the physiological change that occur with age. Endocrine secretions of suc hormones as testosterone, growth hormone and estrogen decrease with age. We begin thi

Hormonal Changes Wi and Resistance Trai

It is well established that, with age, th glands' ability to secrete hormones de any of the body's structures, endocrine go through a cellular aging process exercise and training may offset the

of decreases in the endocrine system's and function. This appears to be mediat stimulation of endocrine glands with r exercise, which results in their synthesi secreting the hormones needed for m homeostasis (during exercise) and for signaling (during recovery).

Despite exercise training, as we age t crine system loses its ability to secrete h in response to exercise; however, withou training this process can be more dram result of disuse. Compromised glandular results in reductions in resting concentr hormones, including anabolic hormo concept of a compromised endocrine s supported by early studies of testoster growth hormone, in which a reduced res ness to resistance exercise stimuli in old

Body Composition Changes in Seniors

Body composition describes the percen mass and various components of fat-f including muscle, bone, tissue, and orga body. With age, all components of body tion tend to change. This section is a rev effects of body composition change on re abolic rate and includes a discussion of th in bone, tissue, and muscle with aging. I training's effects on metabolic rate, mus and tendon can help people maintain during aging. The overall performan

BOX 11.1 **RESEARCH**

Resistance Training and Age-Related Obesity

One might ask the question, Is obesity related only to age, and what might resistan help? Obesity appears to increase with normal aging, from 18% in young adults t in middle age. At the age range of 45 to 65 years, obesity affects 9% of Asian Am white Americans, 35% of Hispanic Americans, and 41% of black Americans. Altho in obesity up to age 65 appears to support an association between age and obesity, falls to 24.7% after age 65 (Mendez 2010). The rationale for this is not entirely c related to decreased life expectancy in those with obesity, resulting in a greater prop people surviving long enough to be surveyed after age 65. In nonsmokers who are life expectancy drops from 81 years to between 68 and 76 years in white men and between 59 and 74 years in black men (Finkelstein et al 2010). The decrease in c years could also be a function of malnutrition in seniors.

The prevalence of obesity at any age warrants action. In conjunction with nutr tions and cardiorespiratory exercise, resistance training may help to address the i fat. Resistance training for 26 weeks increased total energy expenditure in older adu and contributed to greater oxidation of lipids (Hunter et al. 2000). The increa expenditure and spontaneous activity in seniors may have been related to increase caused by resistance training (Jubrias et al. 2001). With six months of resistance oxidative ability increased 57%, muscle size increased 10%, and mitochondrial increased 31%. Thus, along with other treatments, resistance training can help co fat mass in seniors.

Finkelstein, E.A., Brown, D.S., Wrage, L.A., Allaire, B.T., and Thomas, J.H. 2010. Individual and aggreg associated with overweight and obesity. *Obesity* 18: 333-339.

BOX 11.2 **RESEARCH**

What Are the Benefits of Resistance Exercise for Joi

Osteoarthritis (OA) is one of the most common diseases of old age and is frequen by practitioners who work with seniors. It is characterized by loss of cartilage subsequent overcompensation of bone growth to repair the damage. This growth cartilage loss issue, causing a painful, joint-wide problem (Fransen et al. 2009). OA joint ailment with the effects specific to the joint affected (e.g., hip, knee, shoulder) location within that joint (medial, lateral, anterior, posterior, combination), and grade of severity (grade 1 is the mildest; grade 4 is the most severe). Resistance exer for older people with OA because it results in increased strength, improved functio pain (Latham and Liu 2010).

Many people avoid exercise when joint pain is present, but exercise can improve cl A recent meta-analysis examined the effect of resistance training interventions o rheumatoid arthritis, and fibromyalgia in people with an average age of over 50 ye 2011). The meta-analysis found significant improvements in pain and physical fun rate of adverse events across studies. The improvements were also clinically impo those expected from analgesic agents such as acetaminophen and NSAIDS. Thus, re interventions can be an important therapeutic aid for joint pain in seniors.

Fransen, M., McConnell, S., Hernandez-Molina, G., and Reichenbach, S. 2009. Exercise for osteoarthritis

BOX 11.4 **PRACTICAL QUESTION**

What Is the Minimal Amount of Protein Needed by S

Inadequate energy intake may reduce the body's ability to remodel tissues and is c
factors in the decrease of muscle mass with age. In addition a lack of sufficient pro
amount of protein accretion and muscle fiber hypertrophy that can occur with resi
Although many have voiced concerns that higher protein intake could have negat
quences, research has demonstrated that, with the exception of specific medical c
are no contraindications for higher protein intake in seniors (Wolfe, Miller, and Mi
In fact, given their increased needs for immune function and healing, it appears
seniors require up to 1 g · kg^{-1} · day^{-1} regardless of training status. With whole-body
ing they may need even more protein to allow for adequate nitrogen availability
size increases with whole-body programs (Chernoff 2004; Evans 2001). Thus, wh
hypertrophy are factored in, adequate protein intake may exceed the recommended
of 0.8 g · kg^{-1} · day^{-1} (Campbell and Evans 1996; Campbell et al. 2001).

Subjects who consumed a supplement containing protein, carbohydrate, vitamin
fat (accounting for an additional 8 kilocalories and 0.33 grams of protein per kilogra
mass per day) during a 12-week resistance training study showed a greater increase
than those who did not receive supplementation (Meredith et al. 1992). It has also b
protein supplementation before and after a workout (nutrient timing) optimizes p
for both younger and older people (Esmarck et al. 2001). Whether through supp
diet, adequate protein intake is an important factor in health and for optimal ad
neuromuscular system when seniors perform resistance training.

Campbell, W.W., and Evans, W.J. 1996. Protein requirements of elderly people. *European Journal of (*

Summary

Resistance training can be safely and su
implemented in older populations. Eve
and very sick elderly can gain benefits th
itively affect their quality of life. Muscl
and power carries over into the enhan
everyday activities and quality of life,
affecting a long list of physiological char
especially in muscle, bone, and connec
Some of the findings in this chapter
common beliefs that power training
tional resistance training are inappro
elderly people. Traditional resistance tr
power training for this population are
long as the program is properly designe
supervised, and appropriately account
vidual characteristics, such as clinical
and social, psychological, and econom

Women and Resistance Tr

After studying this chapter, you should be able to

1. understand the performance differences between men and women,
2. identify sex differences between men and women in upper- and lower-boc both a relative and absolute perspective,
3. understand sex differences related to hormonal function and response exercise,
4. identify the key sex differences between men and women in muscle fib
5. understand the effects of different resistance training programs for wor
6. understand the different phases of the menstrual cycle and factors relat dysfunction

Women of all ages have realized the benefits of resistance exercise and an overall active lifestyle. Resistance exercise is common among women, particularly those who are fitness enthusiasts, soldiers, and other tactical professionals (e.g., police officers and firefighters). Whether for health and fitness benefits or strength, power, and performance (or both), resistance training is a necessary component of a total conditioning program (see figure 9.1).

This chapter addresses an array of issues related to training for women. With few exceptions, women can perform almost identical programs as men because few major sex differences exist that affect resistance training program design. Women experience the same physiological acute and

Physiological and Differences Betw

The sex differences between r often obvious. Underscoring a fundamental fact of biolog tosterone on muscle cells du along with the androgenic cl both boys and girls as they ences in physiological respon differences related to strengtl trophy. Even at the highest l in weightlifting and powerlif for body weight classificatior than women in lifting perforr

Differences in Muscle Fiber S
Type, and Composition

Prior to describing the sex differences in
performance parameters (strength anc
between men and women, it is important
stand any underlying differences in musc
First, although men and women both pc
same types of muscle fibers, some of the
might be different in some comparisons. I
person to the next, muscle fiber character
vary according to total muscle and mus

(Bergeron et al. 2011).

Body Composition

Body composition changes are a goal of many women and men performing resistance training. Increases in fat-free mass and decreases in percent body fat from short-term (8 to 20 weeks) resistance training programs are of the same magnitude in both sexes. Men and women performing identical short-term weight training programs have both shown significant decreases in percent body fat with no significant difference shown between the sexes (Staron et al. 2000). It has also been reported that both sexes show a significant increase in fat-free mass and no change in percent body fat when performing the identical weight training program for 24 weeks (Lemmer et al. 2001). In this study only men showed a significant reduction in fat mass, indicating that women may have a more difficult time losing body fat during resistance training.

Body composition changes in various regions of the body after training may also be an important consideration in women (Nindl et al. 2000). After six months of performing a periodized weight training program and endurance training exercise, women showed a 31% loss in fat mass with no change in lean mass in the arms. They also showed a 5.5% gain in lean mass in the legs, but no change in fat mass. These results indicate that women may have more difficulty increasing lean mass in the upper body than in the lower body. However, other data dramatically contradict this assertion. After performing several weight training programs for six months, untrained women demonstrated upper-arm muscle cross-sectional area increases from approximately 15 to 19% and increases in thigh muscle cross-sectional area from approximately 5 to 9% (Kraemer et al. 2004). This indicates that the upper-arm musculature undergoes greater hypertrophy than the thigh (again, see figure 9.8).

This conclusion is supported by another report of increased lean tissue in the upper but not

Women's Hormon to Resistance

The acute and chronic ho resistance training affects t environment to which mus This is true for both sexes a gains in muscle size and str training. When interpreting response to training, the p menstrual cycle must be hormone concentrations ca on the phase of the menstr be remembered that a lov hormone does not necessari mone does not have an activ bodily function or process, Hormones at low concentra bodily function as a result o with receptors, higher rates possible effect of a low horn discussed in box 9.1.

Testosterone

At rest, men normally have testosterone in circulation t mer et al. 1991; Vingren et a This may account in part for of men compared to wome affects the developmental signal to make protein, and i of cell-signaling processes in of satellite cells and neuron in chapter 3, testosterone r exercise depend on several amount of muscle mass acti lation of the acute program intensity and the volume of (Fragala et al. 2011a; Kraem

Even though the resting trations of women are low

BOX 9.2 **RESEARCH**

The Role of Estradiol in Exercise-Induced Endocrine R

Compared to men, women have an attenuated inflammatory response to muscle fatigue more slowly than men do in response to acute exercise stress (Fragala et differences are generally in part attributed to sex-specific circulating hormone l estradiol in women and testosterone in men. In women, estradiol functions a and membrane stabilizer during exercise, particularly exercise that induces high l stress, such as intense aerobic and resistance exercise. The protective role of estrad a primary factor in mitigating muscle damage due to exercise stress and is evide inflammatory response seen in women. Even at rest, women have lower levels of ci kinase, one of the most commonly measured markers of muscle damage, in th men. Although estradiol response to resistance exercise must be further researche role of estradiol indicates that it has important implications for women in terms

Performance During the Menstrual Cycle and Menstrual Problems

Lebrun (1994) noted little or no difference i aerobic and anaerobic performance at variou times during the menstrual cycle. No differenc in anaerobic capacity were seen between the mi luteal and midfollicular phases with cycle sprin (Shaharudin, Ghosh, and Ismail 2011). Howeve decrements in performance during the premen strual or menstrual phase have been shown; th best performances occur during the immedia postmenstrual period and the 15th day of th menstrual cycle (Allsen, Parsons, and Bryce 197 Doolittle and Engebretsen 1972; Lebrun 1994 Likewise, peak power, anaerobic capacity, an fatigue rate (Wingate test) have been shown t be negatively affected during the follicular pha compared to the luteal phase (Masterson 1999 Individual variations in the effects of menstru cycle phase on performance can be substantia some athletes even notice an improvement i performance during menstruation (Lebrun 1994

Reasons for decreased performance during th premenstrual or menstrual phase may be assoc ated with many factors, including self-expecta cies, negative attitudes toward menstruation, an weight gain. Although the effect of controllin premenstrual symptoms and dysmenorrhea wit oral contraceptives is unclear, some anecdotal an retrospective studies have reported increases i performance with the use of oral contracepti (Lebrun 1994). The possible detrimental effe on athletic performance of premenstrual sym toms or dysmenorrhea has led some researche to recommend the use of oral contraceptives

BOX 9.3 PRACTICAL QUESTION

Can Strength Training Be Beneficial to Menopausal W

With an increasing life span, more females are living longer after menopause. Me many physiological changes that increase the risk of many diseases, such as diab hypertension as well changes in body composition. Diet and exercise are recomm these changes. Menopause is associated with sarcopenia and osteopenia (Leite et a resistance training has been shown to increase bone and muscle mass as well as str to be an appropriate treatment for some of the changes that occur during meno despite the potential benefits, studies examining the effects of resistance training women are lacking. Studies are needed for elucidating the precise molecular and in anisms that lead to the negative responses of the body during menopause, and to dose–response for the prescription of resistance training for menopausal women.

BOX 9.4 PRACTICAL QUESTION

Can Strength Training Reduce the Risk of Knee Ir

When quadriceps strength is significantly greater than the strength of the ham hamstrings and anterior cruciate ligament (ACL) become more susceptible to inj are responsible for preventing anterior translation of the tibia on the femur. I can produce more anterior translation than the hamstrings and ACL can tolerat Therefore, increasing the strength of the hamstrings in relation to the quadriceps co reduce the risk of ACL injury in women.

Six weeks of emphasizing hamstring-strengthening exercises in the strength of 12 NCAA Division I female soccer players showed a possible reduction of kn addition to other strength and conditioning exercises, the straight-leg deadlift, goo hyperextension, resistance machine single-leg curl, resisted sled walking, and exe were performed twice per week. All of these exercises involve the hamstring mu the six weeks of training the functional ratio increased from 0.96 to 1.08 (Holco Functional ratio was calculated as eccentric hamstring isokinetic torque divided by riceps isokinetic torque. This ratio when greater than 1.0 indicates a decrease in th cruciate ligament injury (Li et al. 1996). Therefore, strength training may be bene ACL injuries, which are particularly common in females.

Summary

Although women's absolute strength is l
men's, the difference is greatly reduced
existent if expressed relative to fat-free
muscle cross-sectional area. Women's low
strength relative to fat-free mass is more ec
to men's than is their upper-body strength
of a greater relative distribution of wom
free mass in the lower body. Women's ada
to resistance training programs are gen
the same magnitude or even slightly grea
men's for some variables. This emphasize
general, resistance training programs for
do not need to be different from those f
except that the absolute resistance used by
will be less. A focus on the use of more upp
exercises to stimulate and maximize the u
available motor units might be one im
aspect to optimize upper-body developm
addition, the use of periodized trainin
paramount to ensure long-term resistance
adherence and adaptational effectiveness

In most cases, physical activity has b
impacts on the menstrual cycle and prem
syndrome in women. Menstrual irregulari
as amenorrhea may be more prevalent in
performing strenuous activity than in the
population, particularly in sports empl
lean body mass and subjective scoring
These menstrual irregularities typically
an energy imbalance and may be associa
the female athlete triad of amenorrhea, di
eating, and osteoporosis. In the case of di
eating, screening for eating disorders and
logical follow-up, if necessary, is essenti
energy level is restored, menstrual anoma
ically disappear and bone density often ir
although the person should be monit