Flexibility in Dance

Martine A. Deighan, B.Sc.(Hons), Ph.D.

Abstract

Dance, and in particular ballet, is characterized by beautiful body shapes and lines, much of which are due to flexibility. Without adequate flexibility, dancers are unlikely to raise themselves to professional standards. However, with such importance placed on this fitness-related parameter, there is a surprising lack of published data on dancers that examines flexibility in relation to injury risk and muscular performance. The following review summarizes the main findings from the dance, sports, and medical literature.

The ability to achieve seemingly impossible positions is one of the main components of a dancer's facility. Dance is communication through human movement, therefore optimum levels of flexibility, or range of motion (ROM), are essential for maximizing the versatility of movement. Yet, of all key components of a dancer's fitness, flexibility is by far the least researched. Flexibility has been described as a combination of muscle extensibility and joint mobility and defined as "the individual's ability to move a joint through its entire range of motion without undue stress to the involved musculotendinous unit."[1] In dance, typical extreme joint positions commonly involve hip flexion, extension and outward rotation, spine extension and ankle plantar flexion.

The factors that limit joint ROM have been separated into general factors accounting for about 5% of flexibility, muscular factors, which can contribute about 10% to flexibility, and finally joint factors, which can contribute around 85% to flexibility performance.[1] Examples of joint factors are articulating bone and cartilage surfaces and ligaments. Muscular factors include muscle and tendon extensibility, fibrous and elastic connective tissue, and muscle fat concentration. General factors are age, sex, body fat, and environmental temperature. Since joint factors are largely hereditary, the potential for young dancers to achieve optimum flexibility for functional and aesthetic purposes is probably constrained by their genes. Selection procedures at auditions to dance schools are careful to test for sufficient flexibility.[2] In several studies[3-6] greater flexibility has been found in student and professional ballet dancers compared to non-dancers, although the opposite has been found in hip internal rotation,[5] but the relative contributions of nature and nurture to flexibility are unresolved.

A flexible ankle-foot complex is essential in ballet for absorbing impact forces from landings[7] and a minimum of 90° of plantar flexion created by ankle and instep is required in the pointe position. Even more ROM is needed if the dancer has recurvatum (hyperextension) at the knee. Any shortfall in plantar flexion ROM means the dancer will not be able to stay up on pointe due to the extra energy required to maintain a plantar flexed position. Achilles tendon strain is a common injury in dancers with insufficient plantar flexion ROM for pointe work.[8] Where ligament tightness is not a limiting factor in maximum plantar flexion ROM, the bone contact between the posterior portion of the talus with the tibia acts as a permanent stop to further plantar flexion.[7]

In a recent review of the impact of stretching on sports injury risk, Thacker and colleagues[9] found 27 reports published since 1962 that demonstrated increase in ROM due to stretching about the ankle, knee, hip, spine, and shoulder. These studies used a variety of stretching techniques, namely static, ballistic, and proprioceptive neuromuscular facilitation (PNF), the latter involving variations of the contract-relax technique reviewed by Shrier and Gossal.[10] No studies have assessed which of these is the most effective in improving flexibility in dancers. In non-dancer populations, PNF has been found to be more effective than

Martine A. Deighan, B.Sc.(Hons), Ph.D., is a Senior Lecturer in the School of Sport and Leisure, University of Gloucestershire, Longlevens, Gloucester, England.

Correspondence: Martine A. Deighan, B.Sc.(Hons), Ph.D., School of Sport and Leisure, University of Gloucestershire, Oxstalls Lane, Longlevens, Gloucester GL2 9HW, England.

static or ballistic stretching,[11-13] but at least one other study did not support this finding.[14] A 30s stretch has been found to be more effective than shorter duration stretches,[15] but as effective as stretches of longer duration.[16] Shrier and Gossal[10] suggested that, although there is a small risk of injury during ballistic stretching, it is more controlled than most athletic movements and therefore is likely to be much less dangerous than the sport itself if not performed too aggressively.

Turnout

The main physical requirement that is unique to dance, particularly ballet, is the external rotation of the lower limb (i.e., turnout). Most non-dancers have 50° turnout and professional ballet dancers have up to 10° more.[17] The factors associated with the degree of turnout from the hip are many, with the length of the iliofemoral ligament being one of the most important. It has been suggested that 42% of the total turnout comes from below the knee compared to 58% from above the knee.[17] However, externally rotating the lower extremity beyond its limits, by using the friction force between shoe and floor to externally rotate the tibia relative to the femur, is likely to encourage biomechanically and aesthetically unfavorable compensations such as anterior pelvic tilt with hyperextension of the lumbar spine and a rolling-in or pronation of the foot.[18] Also, the knee ligaments may be stretched, the articular cartilage compressed, and the patella misaligned.[19]

Grossman[20] described methods for measuring passive and active turnout. Assessment of passive turnout involves the examiner moving the joint into its ROM limit with the subject in a prone or supine position in order to assess the passive contributions of the hip, knee, and ankle using a goniometer. Assessment of active (functional) turnout is achieved using solely the dancer's muscle activation, either in a standing position on the floor or on rotational disks. The virtually friction-free mechanism of the disks means that a dancer cannot over-rotate using excessive contributions of external rotation from the knee and ankle. It has been suggested[20,21] that if the passive turnout is greater than the active turnout measurement, it is an indication that a dancer uses a forced turnout due to a muscular weakness or soft-tissue tightness and this will provide the clinician with information with which to base strengthening or stretching program.

The question of whether turnout can be increased in ballet dancers has been addressed by Khan and associates[22] who assessed active total turnout standing on the floor and hip turnout lying supine with lower leg hanging vertically in 48 male and female 16- to 18-year-old elite ballet dancers over a 12-month period. They found that hip external rotation increased by 4° over 12 months but could not be certain of the clinical significance of this change. Also, although there was no statistically significant difference, these researchers found that in some individual cases active hip external rotation increased with an associated decrease in the below hip external rotation, calculated as the difference between total external rotation standing and hip external rotation supine. These researchers suggested that this latter finding reflected a more technically correct turnout. They also found that the first-year students (16 to 17 year olds) increased left hip external rotation more than the second year students (17 to 18 year olds) over the 12-month assessment indicating a training effect during the first year that reached a plateau in the second.

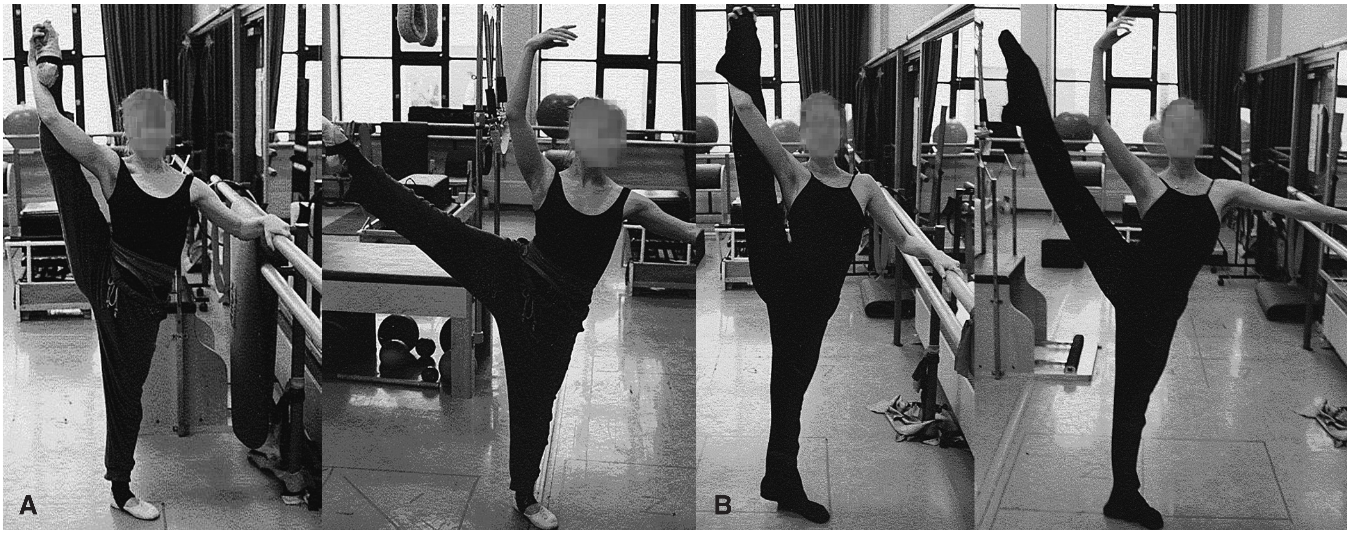
It is worth noting in any assessment of turnout that dancers will use the amount of turnout that looks good and puts the muscles into the optimal length for tension generation, especially for explosive movements, so the actual turnout a dancer uses for certain dance movements may differ from statically measured active turnout. There are no studies that assess the improvement, if any, in turnout capability in skeletally immature populations. Therefore, whether turnout is a trainable component of a dancer's repertoire or is inherent and fairly static due to anatomical limitations remains to be studied.

Hypermobility

As sufficient ROM is essential for choreographic demands, flexibility is an important selection criterion for dance schools and companies.[21] Extreme joint mobility (hypermobility or hyperlaxity) (i.e., an increased flexibility of joints beyond the ROM that is considered normal) is seen as an asset in the dance profession. However, such conditions may put some dancers at risk of instability and injury due to poor joint stabilization.[17,23] Klemp and coworkers[3] found a hypermobility rate of 9.5% among 377 ballet dancers, which is greater than the rate of 4% to 7% demonstrated in the general population.[7] Similarly, a higher incidence of spine hypermobility has been found in 10-year-old ballet dancers in the first year of ballet school compared to controls.[2] In the latter study, most of the dancers had not regularly practiced ballet before, highlighting that spine hypermobility is more likely to be hereditary than the result of ballet training.

In the sports medicine literature, there is evidence of a relationship between injury and both ligamentous laxity and muscle tightness. Krivickas and Feinberg[24] found that in male (but not female) college athletes, for each additional point on a 9-point ligamentous laxity scale (with 9 indicating hyperlax) the risk of injury decreased by 16%. Also, for each additional point on a 10-point muscle tightness scale (10 indicating all muscles tight), the risk of injury increased by 23%. This finding contradicts that of other studies[3,25] that have found a positive association between hypermobility and increased injury risk. This controversy may be due to the fact that ligament laxity is more advantageous in certain activities than others. It may also be that the relationship between joint laxity and injury is a U-shaped curve with very high and low levels of laxity resulting in a higher risk of injury.

Gannon and Bird[6] used the same 9-point hypermobility scale with ballet dancers and gymnasts and found that females were more lax than males but that neither the dancers or gymnasts could be classified as having hypermobile joints, although joint mobility was greater compared to controls. This study also measured passive and active range of motion using a hydrogoniometer. The fact that passive ROM was always greater than active ROM (i.e., that achieved by



Passive Active Passive Active

Figure 1 Dancer A has a higher passive to active range of motion ratio than dancer B during a la seconde.

muscle activation) highlighted the fact that dancers need to increase the active to passive ROM ratio and, therefore, make the joint more stable. There appears to be no studies that have directly examined the active versus passive ROM relationship in relation to injury in dancers. Figure 1 illustrates the difference between active and passive ROM in an a la seconde position. Desfor[23] recommends that more research is required to find the most reliable methods to assess hypermobility as well as the functional control dancers have over hypermobile joints.

Flexibility and Injury

The risk of injury to the soft tissues is based on the notion that "tight" muscles are more likely to be strained.[7] Extensibility in these soft tissues is related to the resistance of the tissues as they are lengthened. More compliant soft tissues can be stretched further or achieve greater strain (percent increase in length) for a given stress (force per tissue area) and can withstand greater stresses.

In a review of the relationship between stretching and injury prevention, Witvrouw and colleagues[26] stated that an injury prevention program should contain flexibility exercises (i.e., stretching) in order to increase the compliance of the tendon unit so that more energy can be absorbed. The rationale for this is that the compliant tendon can absorb more energy when the muscle is activated to a high level so that trauma is reduced to the muscle fibers. In contrast, when the tendon is less compliant, forces will be transferred to the muscle contractile elements, increasing the risk of muscle injury, especially during the stretch-shortening cycle (SSC) (i.e., an eccentric muscle action followed by a concentric action of the same muscle or muscles using the energy stored during the eccentric phase).

Any movement in dance where the body is propelled away from the floor, such as hops, springs and jumps, involves the SSC. However, there is no evidence in the dance science literature to support or refute this relationship between tissue compliance and injury, although there is evidence of ankle ROM having no predictive value of self-reported lower limb injury in ballet and modern college dance students.[27] Contrary to this, Hamilton and associates[17] found that male dancers who had suffered 4 or more injuries had greater active hip flexion ROM and greater elbow extension. There is evidence in the literature that hamstring and quadriceps muscle-tendon unit flexibility is a significant determining factor in patellar tendonopathy, whereas strength and anthropometric factors are not significant predictors.[28]

It seems that the contradictory reports of the relationship between flexibility and injury in the literature may be due to the type of activity in which the sample population participate, with ballistic activities involving a much stronger relationship between flexibility and injury than activities that do not use the SSC, such as cycling and swimming.[26] Therefore it seems, from the sport literature at least, that stretching is an essential part of a dancer's training, if not only for technique and aesthetic purposes but also for injury prevention.

Stretching just prior to exercise does not prevent overuse or acute injuries.[29] However, it is debatable whether this evidence can be related to dance where extreme joint positions must be reached with ease, something only achievable after warm-up stretches. A study of elite figure skaters found that the incidence of injury was lower compared to those in other physical activities.[30] The researchers attributed this to the typically long warm-ups and stretching exercises that are carried out prior to each training session or competition. Volianitis and coworkers[31] suggested that the dancers and their teachers should learn lessons from this example since dancers have high injury rates which may be due to low attention to warm-up routines. McNair and Stanley[32] found that jogging for 10 minutes was not as effective in increasing ankle ROM as stretching for 30 seconds five times or a combination of stretching and jogging. There are no studies of dancers that have separated out the effects of the aerobic component and stretching component of the warm-up on injury rates.

Flexibility training itself has been highlighted as an actual cause of injury in dancers. Askling and colleagues[33] questioned 98 elite ballet dancers aged 17 to 25 years and found that 34% of dancers had experienced an acute injury to the rear thigh and of those injuries 91% were located in an area close to the ischial tuberosity. Significantly, 88% of dancers stated that the injury occurred during slow activities in flexibility training, mainly the splits in the sagittal plane and mostly in the warm-up or cool down, and only 12% of injuries occurred during powerful movements involving the SSC (such as grande jeté). This contradicts most schools of thought that a soft tissue injury is most likely to happen when the tissue is stretched quickly, since under this condition the tissue exhibits greater stiffness compared to a slowly stretched tissue and will reach the peak stress and failure point with less strain (percent elongation). These investigators[33] suggested that a high pain threshold in dancers when performing static stretches may have contributed to these findings. Nevertheless, static stretching should be employed carefully, especially in the cool-down when the muscle-tendon complex is fatigued.

In a study of 17 professional ballerinas, Koutedakis and coworkers[34] found that, contrary to the expectation of reduced joint flexibility after a 6 week summer holiday, there was an average 15% increase in total flexibility measured from hip flexion, trunk extension, and shoulder flexion. This level of flexibility after the break was maintained at the same level when it was tested again 2 to 3 months after the end of the break. The authors speculated that the reason for the lower flexibility at the end of the season was due to accumulated fatigue or burnout. This is in line with a published report[35] indicating that elite athletes are more likely to become injured or over-trained at the end rather than the beginning of their competition season. There are no published data on the injury patterns in dancers over an entire year, but the above evidence supports an investigation into the mechanisms of overtraining in dancers, especially at the end of the season when injuries may be more likely to occur.

Effect of Stretching on Muscular Performance

Although stretching as part of a warm-up is normal procedure before performance in sport and especially in dance, there is evidence, some contradictory, that the acute effects of stretching are deleterious to subsequent muscular performance.

For example, exercises involving PNF have been found to negatively affect[36] or have no effect on subsequent vertical jump performance.[37] Static stretching has been found to reduce muscle strength at slow contraction velocities,[38] with the effect lasting between 1 to 2 hours.[39,40] Static stretching has also been reported to decrease vertical jump performance in some studies[27,41] but not others,[36,39] reduce reaction time and balance ability, the latter due to a reduction in proprioceptive sensitivity,[42] and have no effect on the kinematics of the vertical jump,[43] probably due to neuromuscular inhibition. An increase in rating of perceived exertion has also been reported during submaximal fatiguing knee extension-flexion exercise after static stretching.[44] Ballistic stretching has been found to significantly reduce knee flexion and extension 1 repetition maximum (1RM) by an average of 6.4%.[45] The long-term effects of PNF, however, seem to have a positive effect on muscle strength with an average increase of 21.6% in knee extension and flexion peak torque recorded after 8 weeks of PNF training.[46]

Explanatory mechanisms for the reduction in muscular performance include a loss of force production due to increases in muscle-tendon unit length leading to an unloaded shortening of the muscle during which the slack in the muscle-tendon unit is taken up until the elastic components are able to transmit force to the bone.[47] Other explanations include a dampened excitatory stretch reflex mediated by the muscle spindles[40] or a Golgi tendon organ mediated autogenic inhibition.[37] The fact that these two reflex mechanisms are thought to be altered only during the stretch questions these explanations. Regardless of the true mechanism, it appears that the majority of research, albeit in nondancer populations, finds that stretching before strength or power performance is detrimental to that performance.

Conclusions

Joint flexibility in dancers is essential for correct and efficient execution of the art form. The extent of the trainability of flexibility in dancers remains to be determined. An important issue for dancers in terms of performance and joint stability, but which is not often assessed, is the passive-to-active ROM ratio, with higher values indicating lower joint stability or deficit in muscular strength. Dance-specific studies of flexibility are required to determine the relative contributions of heredity and training to joint flexibility and the short- and long-term effects of different stretching modalities.

References

1. Koutedakis Y, Sharp N: The Main Physical Fitness Components and Dance. *In:* Koutedakis Y, Sharp N (eds): *The Fit and Healthy Dancer*. Chichester, England: John Wiley and Sons, 1999, pp. 128-141.
2. Nilsson C, Wykman A, Leanderson J: Spinal sagittal mobility and joint laxity in young ballet dancers: A comparative study between first-year students at the Swedish Ballet School and a control group. Knee Surg Sports Traumatol Arthrosc 1(3-4):206-208, 1993.
3. Klemp P, Learmonth I: Hypermobility and injuries in a professional ballet company. Br J Sports Med 18(3):143-148, 1984.
4. Chatfield S, Byrnes W, Lally D, et al: Cross-sectional profiling of modern dancers. Dance Research Journal 22(1), 1990.
5. DiTullio M, Wilczek L, Paulus D, et al: Comparison of hip rotation in female classical ballet dancers versus female nondancers. Med Probl Perform Art 4(4):154-158, 1989.
6. Gannon L, Bird H: The quantification of joint laxity in dancers and gymnasts. J Sport Sciences 17:743-750, 1999.
7. Alter M: *Science of Flexibility* (3rd ed). Champaign, Illinois: Human Kinetics Publishers, Inc., 2004.
8. Hamilton W: Ballet and your body: An orthopaedist's view. Dance Magazine 52(8):84-85, 1978.

9. Thacker S, Gilchrist J, Stroup D, et al: The impact of stretching on sports injury risk: A systematic review of the literature. Med Sci Sports Exerc 36(3):371-378, 2004.
10. Shrier I, Gossal K: Myths and truths of stretching. Br J Sports Med 28(8):57-63, 2000.
11. Entyre B, Lee E: Chronic and acute flexibility of men and women using three different stretching techniques. Res Q 59:222-228, 1988.
12. Wallin D, Ekblom R, Grahn R, Nordenborg T: Improvement of muscle flexibility: A comparison between two techniques. Am J Sports Med 13:263-268, 1985.
13. Sady S, Wortman M, Blanke D: Flexibility training: Ballistic, static or proprioceptive neuromuscular facilitation. Arch Phys Med Rehabil 63(6):261-263, 1982.
14. Lucas R, Koslov R: Comparative study of static, dynamic and proprioceptive neuromuscular facilitation stretching techniques on flexibility. Percep Mot Skills 58:615-618, 1984.
15. Roberts J, Wilson K: Effect of stretching duration on the active and passive range of motion in the lower extremity. Br J Sports Med 33:259-263, 1999.
16. Bandy W, Irion J: The effect of time on static stretch on the flexibility of the hamstring muscles. Phys Ther 74: 845-852, 1994.
17. Hamilton W, Hamilton L, Marshall P, et al: A profile of musculoskeletal characteristics of elite professional ballet dancers. Am J Sports Med 20(3):267-273, 1992.
18. Milan K: Injury in ballet: A review of relevant topics for the physical therapist. J Sports Phys Ther 19(2):121-129, 1994.
19. Scioscia T, Griffin J, Fu F: Knee ligament and meniscal injuries in dancers. J Dance Med Sci 5(1):11-15, 2001.
20. Grossman G: Measuring dancer's active and passive turnout. J Dance Med Sci 7(2):49-55, 2003.
21. Liederbach M: Screening for functional capacity in dancers. J Dance Med Sci 1(3):93-106, 1997.
22. Khan K, Bennell K, Ng S, et al.: Can 16-18-year-old elite ballet dancers improve their hip and ankle range of motion over a 12-month period? Clin J Sport Med 10:98-103, 2000.
23. Desfor F: Assessing hypermobility in dancers. J Dance Med Sci 7(1):17-23, 2003.
24. Krisckivas L, Feinberg J: Lower extremity injuries in college athletes: Relation between ligamentous laxity and lower extremity muscle tightness. Arch Phys Med Rehabil 77:1139-1143, 1996.
25. Graham R, Jenkins J: Joint hypermobility: Asset or liability. Ann Rheumatol Dis 31:109-111, 1972.
26. Witvrouw E, Mahieu N, Danneels L, et al: Stretching and injury prevention: An obscure relationship. Sports Med 34(7):443-449, 2004.
27. Wiesler E, Hunter D, Martin D, et al: Ankle flexibility and injury patterns in dancers. Am J Sports Med 24(6):754-757, 1996.
28. Witvrouw E, Bellemans J, Lysens R, et al: Intrinsic risk factors for the development of patellar tendinitis in an athletic population: A two years prospective study. Am J Sports Med 29(2):190-195, 2001.
29. Shrier I: Stretching before exercise does not reduce the risk of local muscle injury: A critical review of the clinical and basic science literature. Clin J Sports Med 9:221-227, 1999.
30. Kjaer M, Larrson B: Physiological profile and incidence of injuries among elite figure skaters. J Sports Sci 10: 29-36, 1992.
31. Volianitis S, Koutedakis Y, Carson R: Warm-up: A brief review. J Dance Med Sci 5(3):75-81, 2001.
32. McNair P, Stanley S: Effect of passive stretching and jogging on the series elastic muscle stiffness and range of motion of the ankle joint. Br J Sports Med 30:313-318, 1996.
33. Askling C, Lund H, Saartok T, et al: Self-reported hamstring injuries in student dancers. Scand J Med Sci Sports 12:230-235, 2002.
34. Koutedakis Y, Myszkewycz L, Soulas D, et al: The effects of rest and subsequent training on selected physiological parameters in professional female classical dancers. Int J Sports Med 20:379-383, 1999.
35. Koutedakis Y, Sharp N: Seasonal variations of injury and overtraining in elite athletes. Clin J Sports Med 8:18-21, 1998.
36. Church J, Wiggins M, Moode F, et al: Effect of warm-up and flexibility treatments on vertical jump performance. J Strength Cond Res 15(3):332-336, 2001.
37. Young W, Elliot S: Acute effects of static stretching, proprioceptive neuromuscular facilitation stretching and maximum voluntary contractions on explosive force and jumping performance. Res Q Exerc Sport 72(3):273, 2001.
38. Nelson A, Guillory I, Cornwell A, et al: Inhibition of maximal voluntary isokinetic torque production following stretching is velocity-specific. J Strength Cond Res 15(2):241-246, 2001.
39. Power K, Behm D, Cahill F, et al: An acute bout of static stretching: Effects on force and jumping performance. Med Sci Sports Exerc 36(8):1389-1396, 2004.
40. Fowles J, Sale D, MacDougall J: Reduced strength after passive stretch of the human plantar flexors. J Appl Physiol 89:1179-1188, 2000.
41. Cornwell A, Nelson A, Sidaway B: Acute effects of stretching on the neuromechanical properties of the triceps surae muscle complex. Eur J Appl Physiol 86:428-434, 2002.
42. Behm D, Bambury A, Cahill F, et al: Effect of acute static stretching on force, balance, reaction time and movement time. Med Sci Sports Exerc 36(8):1397-1402, 2004.
43. Knudson D, Bennett K, Corn R, et al: Acute effects of stretching are not evident in the kinematics of the vertical jump. J Strength Cond Res 15(1):98-101, 2001.
44. Laur D, Anderson T, Geddes G, et al: The effects of acute stretching on hamstring muscle fatigue and perceived exertion. J Sports Sci 21:163-170, 2003.
45. Nelson A, Kokkonen J: Acute ballistic muscle stretching inhibits maximal strength performance. Res Q Exerc Sport 72(4):415-419, 2001.
46. Handel M, Horstmann T, Dickhuth H, et al: Effects of contract-relax stretching training on muscle performance in athletes. Eur J Appl Physiol 76:400-408, 1997.
47. Wilson G, Murphy A, Prior J: Musculotendinous stiffness: Its relation to eccentric, isometric, and concentric performance. J Appl Physiol 76(6):2714-2719, 1994.