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Peter Magnusson; Per Renström

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ORIGINAL ARTICLE

The European College of Sports Sciences Position statement: The role of stretching exercises in sports

PETER MAGNUSSON & PER RENSTRÖM

Introduction

The current document addresses i) the biomechanics of stretching, ii) the effect of stretching on injury risk, and iii) the effect of stretching on performance, while it does not address the effect of stretching in various patient populations or as parts of a rehabilitation regime.

Stretching is the act of performing a particular exercise to improve joint range of motion, while flexibility is traditionally considered the joint range of motion that can be measured at any given time. Flexibility is believed to be an important element of fitness (Corbin & Noble, 1980) and, accordingly, stretching of human skeletal muscle to improve flexibility is a widespread practice among competitive and recreational athletes. However, despite the widespread use and popularity of stretching exercises in sports with the goal to reduce the passive resistance of the muscle-tendon unit, reduce injury risk and improve performance, there is limited or even a lack of documentation with respect to the mechanism and effect of this practice. While much of the knowledge in the area has been based on human studies using goniometric measurement technique and animal models using techniques to evaluate the material properties, there is a growing body of literature based on human models that addresses the mechanical properties of the musculoskeletal system.

A fundamental issue to address is how and to what extent stretching exercises affects the mechanical properties of the muscle-tendon unit, i.e. does the muscle-tendon unit become more compliant (less stiff) as a result of stretching. If the target muscle is held stationary at some new length during so-called static stretching, the resistance to elongation measured as joint moment will decrease with time (Magnusson, 1998). This is called stress relaxation and demonstrates that the muscle-tendon unit is affected *during* the stretch intervention. Some studies have demonstrated this stress relaxation phenomena in a human model (Magnusson et al., 1996d; Magnusson, Simonsen, Aagaard, & Kjaer, 1996a; Magnusson, Simonsen, Aagaard, Sorensen, & Kjaer, 1996b; McHugh, Magnusson, Gleim, & Nicholas, 1992; McNair, Dombroski, Hewson, & Stanley, 2001). With five repeated 90-second static stretches it can be seen that the resistance (and stiffness) to stretch is reduced during the subsequent stretch, indicating that there is an, at least short-term effect of stretching (seconds-minutes) (Magnusson et al., 1996a). However, when the stretch is repeated 1 hour later this effect has vanished (Magnusson et al., 1996a), and when three 45-second stretches are performed immediately after one another, no immediate affect can be seen at all (Magnusson, Aagaard, & Nielson, 2000a). Together these findings suggest that stretching may affect the passive mechanical properties of the muscle-tendon unit during the actual stretch maneuver and for some brief time thereafter, but that this adaptation is very short lived.

Nevertheless, perhaps stretching affects the mechanical properties of the force transmitting structures if it is performed habitually over a longer time period. This important question has been addressed by several investigators. The studies show that up to 4 weeks of stretching for a total of as much as 9,000 seconds in healthy subjects and 36,000 seconds in immobilized human muscle does not affect the resistance to stretch (Bjorklund, Hamberg, & Crenshaw, 2001; Halbertsma & Goeken, 1994; Harvey et al., 2003; Magnusson, Simonsen, Aagaard, Sorensen, & Kjaer, 1996c). In other words, with one exception (Guissard & Duchateau, 2004), the available human data overwhelmingly appears to refute the notion that stretching exercise influences the resistance to stretch in the long term

Correspondence: P. Magnusson, E-mail: p.magnusson@mfi.ku.dk; P. Renström, E-mail: Per.Renstrom@kirurgi.ki.se

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(Magnusson et al., 1996a; Magnusson et al., 2000a; Bjorklund et al., 2001; Halbertsma & Goeken, 1994; Harvey et al., 2003; Magnusson et al., 1996c; Magnusson, Aagaard, Larsson, & Kjaer, 2000b; Halbertsma, Mulder, Goeken, & Eisma, 1999; Laessoe & Voigt, 2004; Magnusson, Aagard, Simonsen, & Bojsen-Moller, 1998). Notwithstanding these relatively new findings, it is apparent to everyone that gains in joint range of motion can readily be achieved by performing stretching exercises. However, these gains in joint range of motion are achieved in the absence of any altered mechanical properties, and therefore it appears that the mechanism for the improved joint range of motion is a tolerance to the imposed stretch (Bjorklund et al., 2001; Halbertsma & Goeken, 1994; Magnusson et al., 1996c; Halbertsma et al., 1999; Laessoe & Voigt, 2004; Magnusson et al., 1998). The exact mechanism of the neural aspect of stretching the muscle-tendon unit remains to be unraveled.

Effects of stretching on injury risk

The practice of performing stretching before exercise prior to participation in sports with the aim to reduce injury has received some attention in the literature in recent review articles (Herbert & Gabriel, 2002; Thacker, Gilchrist, Stroup, & Kimsey, 2004; Shrier, 2005). In a thorough review by Shrier (2005) it was shown that out of 293 articles on the topic a mere 14 included a control group, which therefore warranted further analysis. Five articles suggested that stretching was beneficial while three articles suggested that it was detrimental and six suggested no effect at all. However, the articles that suggested a beneficial effect suffered from the fact that they included multiple interventions, which makes it difficult or impossible to attribute the reduced injury risk to stretching alone. One of the most commonly cited references is that of Ekstrand, Gillquist, and Liljedahl (1983) in which the authors demonstrated that an intervention program that included 1) correction of training, 2) provision of optimum equipment; 3) prophylactic ankle taping; 4) controlled rehabilitation; 5) exclusion of players with grave knee instability; 6) information about the importance of disciplined play and the increased risk of injury at training camps; and 7) correction and supervision by doctor(s) and physiotherapist(s) reduced the injury risk substantially. Naturally the multiple intervention strategy makes it unattainable to attribute any single one to the observed effect.

Other studies are of questionable value because of problems related to the randomization procedure and the use of historical controls (Shrier, 2005). Three cross-sectional studies (Howell, 1984; Jacobs & Berson, 1986; Kerner & D'Amico, 1983) suggest that stretching may actually increase the risk of sustaining an injury, although these studies should be viewed with caution since they did not control for many other factors that may contribute to the injury risk. Six studies (Blair & Kohl, 1987; Brunet, Cook, Brinker, & Dickinson, 1990; Macera et al., 1989; Pope, Herbert, Kirwan, & Graham, 2000; van Mechelen, Hlobil, Kemper, Voorn, & de Jongh, 1993; Walter, Hart, McIntosh, & Sutton, 1989) have demonstrated no effect of stretching on injury risk. One of the most extensive undertaking was that of Pope et al. (2000) who randomized 1,538 military recruits to warm-up with or without added stretching. The results did not support that the stretching intervention had any effect on injury risk. In another study Van Mechelen et al. (1993) randomized 421 runners to a stretching and non-stretching group without demonstrating any effect of the intervention. It should be noted that these types of studies are very difficult to perform: the sample size required is substantial, which makes it costly, and the various factors, including for example previous injury, that need to be controlled for, are numerous and challenging. Notwithstanding these challenges, there is currently no firm evidence that stretching before exercise can reduce the injury risk.

The effects of stretching on performance

It seems to be a well accepted notion that stretching can improve performance in addition to reducing injury risk. Obviously performance of a given sport may be very task specific and highly complex, and such specificity and complexity often precludes it from being measured in the laboratory setting. However, some aspect of performance, such as maximal isometric and dynamic strength, and jump height are more readily measured and analyzed and have thus been examined following a stretching regime. [For a recent review see Shrier (2004)].

There are numerous studies that examine the acute effects of stretching on performance defined as maximal voluntary muscle contraction (1 RM, isometric and isokinetic contraction) or jump performance, and the data show that stretching reduces these kinds of performance tasks (Avela, Kyrolainen, & Komi, 1900; Behm, Button, & Butt, 2001; Behm, Bambury, Cahill, & Power, 2004; Church, Wiggins, Moode, & Crist, 2001; Cornwell, Nelson, & Sidaway, 2002; Cramer et al., 2005; Evetovich, Nauman, Conley, & Todd, 2003; Fowles, Sale, & MacDougall, 2000; Knudson & Noffal, 2005; Kokkonen, Nelson, & Cornwell, 1998; Laur, Anderson, Geddes, Crandall, & Pincivero, 2003; Mcneal & Sands, 2003; Nelson, Guillory, Cornwell, & Kokkonen, 2001a; Nelson, Allen, Cornwell, & Kokkonen, 2001b; Nelson, Kokkonen, & Arnall, 2005a; Power, Behm, Cahill, Carroll, & Young, 2004; Young & Elliott, 2001; Young & Behm, 2003). It is notable that there is no single study suggesting that muscle performance is augmented as a function of stretching. Therefore the evidence overwhelmingly supports the notion that an acute bout of stretching will diminish maximal muscle efforts, including jump performance, immediately after an acute bout of stretching. Both neural and mechanical properties have been implicated, but the mechanism for the stretching associated reduction in performance remains unknown. The effect of stretching on running speed has also been investigated, and these published studies report a lack of effect (deVries, 1962; Pyke, 1968) or a negative effect (Nelson, Driscoll, Landin, Young, & Schexnayder, 2005b) on running speed.

A separate issue is if stretching on a routine basis can affect performance. There are several studies that suggest that stretching on a routine basis other than immediately prior to exercise can improve performance, such as maximal voluntary contraction and jump height (Dintiman, 1964; Handel, Horstmann, Dickhuth, & Gulch, 1997; Hortobagyi, Faludi, Tihanyi, & Merkely, 1985; Hunter & Marshall, 2002; Wilson, Elliott, & Wood, 1992; Worrell, Smith, & Winegardner, 1994). How the magnitude of this augmentation compares with that of other forms of training is largely unexplored. The mechanism for the apparent paradox between the immediate (negative) and long term (positive) effects of stretching regimes remains unknown.

Another type of measurable 'performance' is running economy, i.e. the energy requirement for an individual at a given constant speed of locomotion. Although musculoskeletal flexibility is a combination of neural and the mechanical properties of the muscle-tendon unit (Magnusson et al., 1997), it is of interest to note that muscoskeletal 'tightness' is associated with greater economy of movement, and not vice versa (Gleim, Stachenfeld, & Nicholas, 1990), which is a common notion. In line with the lack of a long term mechanical effect of stretching, habitual stretching over weeks does not appear to affect running economy (Godges, MacRae, & Engelke, 1993; Nelson, Kokkonen, Eldredge, Cornwell, & Glickman-Weiss, 2001c), although one study has shown a small improvement immediately after stretching (Godges, MacRae, Longdon, Tinberg, & MacRae, 1989).

Conclusions

- During passive static stretching stress relaxation occurs, i.e. the mechanical properties of the muscle-tendon unit are affected *during* the actual stretch maneuver, however, this mechanical effect appears to rapidly (minutes) disappear.
- Stretching produces gains in maximal joint range of motion: the mechanism for the augmented joint range of motion is an increased tolerance to applied stretch, rather than a change in the mechanical properties of the muscle-tendon unit.
- The currently available evidence does not support the notion that stretching prior to exercise can effectively reduce injury risk.
- There is no evidence that muscle strength or jump performance will improve with an acute bout stretching. In fact, there is firm evidence that muscle strength and jump performance is diminished immediately after stretching.
- Habitual stretching may improve maximal muscle strength and jump height.
- Habitual stretching is unlikely to improve running economy.

References

Avela, J., Kyrolainen, H., & Komi, P. V. (1900). Altered reflex sensitivity after repeated and prolonged passive muscle stretching. *Journal of Applied Physiology*, *86*(4), 1283–1291.

Behm, D. G., Button, D. C., & Butt, J. C. (2001). Factors affecting force loss with prolonged stretching. *Canadian Journal of Applied Physiology*, *26*(3), 261–272.

Behm, D. G., Bambury, A., Cahill, F., & Power, K. (2004). Effect of acute static stretching on force, balance, reaction time, and movement time. *Medicine & Science in Sports Exercise*, *36*(8), 1397–1402.

Bjorklund, M., Hamberg, J., & Crenshaw, A. G. (2001). Sensory adaptation after a 2-week stretching regimen of the rectus femoris muscle. *Archives Physical Medicine and Rehabilitation*, *82*(9), 1245–1250.

Blair, S. N., & Kohl, H. W. (1987). Rates and risks for running and exercise injuries: Studies in three populations. *Research Quarterly*, *58*, 221–228.

Brunet, M. E., Cook, S. D., Brinker, M. R., & Dickinson, J. A. (1990). A survey of running injuries in 1505 competitive and recreational runners. *Journal of Sports Medicine Physical Fitness*, *30*, 307–315.

Church, J. B., Wiggins, M. S., Moode, F. M., & Crist, R. (2001). Effect of warm-up and flexibility treatments on vertical jump performance. *Journal of Strength and Conditioning Research*, *15*(3), 332–336.

Cornwell, A., Nelson, A. G., & Sidaway, B. (2002). Acute effects of stretching on the neuromechanical properties of the triceps surae muscle complex. *European Journal of Applied Physiology*, *86*(5), 428–434.

Corbin, C. B., & Noble, L. (1980). Flexibility. a major component of physical fitness. *Journal of Physical Education Recreation*, *6*, 23–60.

Cramer, J. T., Housh, T. J., Weir, J. P., Johnson, G. O., Coburn J. W., & Beck, T. W. (2005). The acute effects of static stretching on peak torque, mean power output, electromyography, and mechanomyography. *European Journal of Applied Physiology*, *93*(5-6), 530–539.

deVries, H. (1962). The "looseness" factor in speed and O2 consumtion of an anaerobic 100-yard dash. *Research Quarterly*, *34*, 305–313.

Dintiman, G. B. (1964). Effects of various training programs on running speed. *Research Quarterly*, *35*, 457–463.

Ekstrand, J., Gillquist, J., & Liljedahl, S. O. (1983). Prevention of soccer injuries. Supervision by doctor and physiotherapist. *American Journal of Sports Medicine*, *11*, 116–120.

Evetovich, T. K., Nauman, N. J., Conley, D. S., & Todd, J. B. (2003). Effect of static stretching of the biceps brachii on torque, electromyography, and mechanomyography during concentric isokinetic muscle actions. *Journal of Strength and Conditioning Research*, *17*(3), 484–488.

Fowles, J. R., Sale, D. G., & MacDougall, J. D. (2000). Reduced strength after passive stretch of the human plantarflexors. *Journal of Applied Physiology*, *89*(3), 1179–1188.

Gleim, G. W., Stachenfeld, N. S., & Nicholas, J. A. (1990). The influence of flexibility on the economy of walking and jogging. *Journal of Orthopedic Research*, *8*(6), 814–823.

Godges, J. J., MacRae, H., Longdon, C., Tinberg, C., & MacRae, P. (1989). The effects of two stretching procedures on hip range of motion and gait economy. *Journal of Orthopaedic and Sports Physical Therapy*, 350–357.

Godges, J. J., MacRae, P. G., & Engelke, K. A. (1993). Effects of exercise on hip range of motion, trunk muscle performance, and gait economy. *Physical Therapy*, *73*(7), 468–477.

Guissard, N., & Duchateau, J. (2004). Effect of static stretch training on neural and mechanical properties of the human plantar-flexor muscles. *Muscle Nerve*, *29*(2), 248–255.

Halbertsma, J. P. K., & Goeken, L. N. H. (1994). Stretching exercises: Effect on passive extensibility and stiffness in short hamstring of healthy subjects. *Archives of Physical Medicine and Rehabilitation*, *75*, 976–981.

Halbertsma, J. P., Mulder, I., Goeken, L. N., & Eisma, W. H. (1999). Repeated passive stretching: acute effect on the passive muscle moment and extensibility of short hamstrings. *Archives of Physical Medicine and Rehabilitation*, *80*(4), 407–414.

Handel, M., Horstmann, T., Dickhuth, H. H., & Gulch, R. W. (1997). Effects of contract-relax stretching training on muscle performance in athletes. *European Journal of Applied Physiology*, *76*(5), 400–408.

Harvey, L. A., Byak, A. J., Ostrovskaya, M., Glinsky, J., Katte, L., & Herbert, R. D. (2003). Randomised trial of the effects of four weeks of daily stretch on extensibility of hamstring muscles in people with spinal cord injuries. *Australian Journal of Physiotherapy*, *49*(3), 176–181.

Herbert, R. D., & Gabriel, M. (2002). Effects of stretching before and after exercising on muscle soreness and risk of injury: systematic review. *British Medical Journal*, *325*(7362), 468.

Hortobagyi, T., Faludi, J., Tihanyi, J., & Merkely, B. (1985). Effects of intense "stretching"-flexibility training on the mechanical profile of the knee extensors and on the range of motion of the hip joint. *International Journal of Sports Medicine*, *6*, 317–321.

Howell, D. W. (1984). Musculoskeletal profile and incidence of musculoskeletal injuries in lightweight women rowers. *American Journal of Sports Medicine*, *12*(4), 278–282.

Hunter, J. P., & Marshall, R. N. (2002). Effects of power and flexibility training on vertical jump technique. *Medicine & Science in Sports Exercise*, *34*(3), 478–486.

Jacobs, S. J., & Berson, B. L. (1986). Injuries to runners: A study of entrants to a 10,000 meter race. *American Journal of Sports Medicine*, *14*, 151–155.

Kerner, J. A., & D'Amico, J. C. (1983). A statistical analysis of a group of runners. *Journal of the American Pediatric Medical Association*, *73*(3), 160–164.

Knudson, D., & Noffal, G. (2005). Time course of stretch-induced isometric strength deficits. *European Journal of Applied Physiology*, *94*(3), 348–351.

Kokkonen, J., Nelson, A. G., & Cornwell, A. (1998). Acute muscle stretching inhibits maximal strength performance. *Research Quarterly Exercise Sports*, *69*(4), 411–415.

Laessoe, U., & Voigt, M. (2004). Modification of stretch tolerance in a stooping position. *Scandinavian Journal of Medicine and Science in Sports*, *14*(4), 239–244.

Laur, D. J., Anderson, T., Geddes, G., Crandall, A., & Pincivero, D. M. (2003). The effects of acute stretching on hamstring muscle fatigue and perceived exertion. *Journal of Sports Science*, *21*(3), 163–170.

Macera, C. A., Pate, R. R., Powell, K. E., Jackson, K. L., Kendrick, J. S., & Craven, T. E. (1989). Predicting lower-extremity injuries among habitual runners. *Archives of Internal Medicine*, *149*(11), 2565–2568.

Magnusson, S. P., Simonsen, E. B., Aagaard, P., & Kjaer, M. (1996a). Biomechanical responses to repeated stretches in human hamstring muscle in vivo. *American Journal of Sports Medicine*, *24*(5), 622–628.

Magnusson, S. P., Simonsen, E. B., Aagaard, P., Sorensen, H., & Kjaer, M. (1996b). A mechanism for altered flexibility in human skeletal muscle. *Journal of Physiology*, *497*(Pt 1), 291–298.

Magnusson, S. P., Simonsen, E. B., Aagaard, P., Sorensen, H., & Kjaer, M. (1996c). A mechanism for altered flexibility in human skeletal muscle [published erratum appears in J Physiol (Lond) 1996 Dec 15;497(Pt 3):857]. *Journal of Physiology (Lond)*, *15*;497(Pt 1), 291–298.

Magnusson, S. P., Simonsen, E. B., Dyhre-Poulsen, P., Aagaard, P., Mohr, T., & Kjaer, M. (1996d). Viscoelastic stress relaxation during static stretch in human skeletal muscle in the absence of EMG activity. *Scandinavian Journal of Medicine and Science in Sports*, *6*(6), 323–328.

Magnusson, S. P., Simonsen, E. B., Aagaard, P., Boesen, J., Johannsen, F., & Kjaer, M. (1997). Determinants of musculoskeletal flexibility: viscoelastic properties, cross-sectional area, EMG and stretch tolerance. *Scandinavian Journal of Medicine and Science in Sports*, *7*(4), 195–202.

Magnusson, S. P. (1998). Passive properties of human skeletal muscle during stretch maneuvers. A review. *Scandinavian Journal of Medicine and Science in Sports*, *8*(2), 65–77.

Magnusson, S. P., Aagard, P., Simonsen, E., & Bojsen-Moller, F. (1998). A biomechanical evaluation of cyclic and static stretch in human skeletal muscle. *International Journal of Sports Medicines*, *19*(5), 310–316.

Magnusson, S. P., Aagaard, P., & Nielson, J. J. (2000a). Passive energy return after repeated stretches of the hamstring muscle-tendon unit. *Medicine & Science in Sports Exercise*, *32*(6), 1160–1164.

Magnusson, S. P., Aagaard, P., Larsson, B., & Kjaer, M. (2000b). Passive energy absorption by human muscle-tendon unit is unaffected by increase in intramuscular temperature. *Journal of Applied Physiology*, *88*(4), 1215–1220.

McHugh, M. P., Magnusson, S. P., Gleim, G. W., & Nicholas, J. A. (1992). Viscoelastic stress relaxation in human skeletal muscle. *Medicine & Science in Sports Exercise*, *24*(12), 1375–1382.

McNair, P. J., Dombroski, E. W., Hewson, D. J., & Stanley, S. N. (2001). Stretching at the ankle joint: viscoelastic responses to holds and continuous passive motion. *Medicine & Science in Sports Exercise*, *33*(3), 354–358.

Mcneal, J. R., & Sands, W. A. (2003). Acute static stretching reduces lower extremity power in trained children. *Pediatric Exercise Science*, *15*(2), 139–145.

Nelson, A. G., Guillory, I. K., Cornwell, C., & Kokkonen, J. (2001a). Inhibition of maximal voluntary isokinetic torque production following stretching is velocity-specific. *Journal of Strength and Conditioning Research*, *15*(2), 241–246.

Nelson, A. G., Allen, J. D., Cornwell, A., & Kokkonen, J. (2001b). Inhibition of maximal voluntary isometric torque production by acute stretching is joint-angle specific. *Research Quarterly Exercise Sports*, *72*(1), 68–70.

Nelson, A. G., Kokkonen, J., Eldredge, C., Cornwell, A., & Glickman-Weiss, E. (2001c). Chronic stretching and running economy. *Scandinavian Journal of Medicine and Science in Sports*, *11*(5), 260–265.

Nelson, A. G., Kokkonen, J., & Arnall, D. A. (2005a). Acute muscle stretching inhibits muscle strength endurance performance. *Journal of Strength and Conditioning Research*, *19*(2), 338–343.

Nelson, A. G., Driscoll, N. M., Landin, D. K., Young, M. A., & Schexnayder, I. C. (2005b). Acute effects of passive muscle stretching on sprint performance. *Journal of Sports Sciences, 23,* 449–454.

Pope, R. P., Herbert, R. D., Kirwan, J. D., & Graham, B. J. (2000). A randomized trial of preexercise stretching for prevention of lower-limb injury. *Medicine & Science in Sports Exercise*, *32*(2), 271–277.

Power, K., Behm, D., Cahill, F., Carroll, M., & Young, W. (2004). An acute bout of static stretching: effects on force and jumping performance. *Medicine & Science in Sports Exercise*, *36*(8), 1389–1396.

Pyke, F. S. (1968). The effect of preliminary activity on maximal motor performance. *Research Quarterly*, *39*(4), 1069–1076.

Shrier, I. (2004). Does stretching improve performance?: a systematic and critical review of the literature. *Clinical Journal of Sports Medicine*, *14*(5), 267–273.

Shrier, I. (2005). Does stretching help prevent injuries? *Evidenced Based Sports Medicine*.

Thacker, S. B., Gilchrist, J., Stroup, D. F., & Kimsey, C. D., Jr. (2004). The impact of stretching on sports injury risk: a systematic review of the literature. *Medicine & Science in Sports Exercise*, *36*(3), 371–378.

van Mechelen, W., Hlobil, H., Kemper, H. C., Voorn, W. J., & de Jongh, H. R. (1993). Prevention of running injuries by warm-up, cool-down, and stretching exercises. *American Journal of Sports Medicine*, *21*, 711–719.

Walter, S. D., Hart, L. E., McIntosh, J. M., & Sutton, J. R. (1989). The ontarion cohort study of running-related injureis. *Archives of Internal Medicine*, *149*, 2561–2564.

Wilson, G. J., Elliott, B. C., & Wood, G. A. (1992). Stretch shorten cycle performance enhancement through flexibility training. *Medicine & Science in Sports Exercise*, *24*(1), 116–123.

Worrell, T. W., Smith, T. L., & Winegardner, J. (1994). Effect of hamstring stretching on hamstring muscle performance. *Journal of Orthopaedic and Sports Physical Therapy*, *20*, 154–159.

Young, W., & Elliott, S. (2001). Acute effects of static stretching, proprioceptive neuromuscular facilitation stretching, and maximum voluntary contractions on explosive force production and jumping performance. *Research Quarterly Exercise Sports*, *72*(3), 273–279.

Young, W. B., & Behm, D. G. (2003). Effects of running, static stretching and practice jumps on explosive force production and jumping performance. *Journal of Sports Medicine Physical Fitness*, *43*(1), 21–27.