The Special Operations Medical Association's Official Journal

JSOM

JOURNAL *of* SPECIAL OPERATIONS MEDICINE™

Summer 2015
Volume 15, Edition 2

THE JOURNAL FOR OPERATIONAL MEDICINE AND TACTICAL CASUALTY CARE

Inside this Issue:

Dedicated to the Indomitable Spirit and Sacrifices of the SOF Medic

A Peer-Reviewed Journal that Brings Together the Global Interests of Special Operations' First Responders

INJURY PREVENTION

An Ongoing Series

The Importance of Physical Fitness for Injury Prevention: Part 2

Joseph J. Knapik, ScD

ABSTRACT

This report examines associations between injuries and flexibility, stretching, warm-up, and body composition. Military studies show that either too much or too little flexibility increases injury risk. Static stretching prior to exercise does not appear to reduce the overall injury incidence, although further research is needed on some types of injuries. Static stretching also appears to reduce strength and power (explosive strength). Warm-up (low intensity activity prior to exercise or sports) appears to reduce injury risk. Body mass index (BMI; weight in kg/height in m^2) is a surrogate measure of body fat because it is highly related to laboratory measures of body fat. However, Soldiers can also have a high BMI because of higher muscle mass. If high BMI reflects a larger percentage of body fat relative to height, injury risk might be increased because the additional fat would increase the intensity of physical activity, leading to more rapid fatigue and repetitive stress on the musculoskeletal system. Low BMI could reflect a paucity of fat or muscle/bone, or both. Low BMI may make Soldiers more susceptible to injury if they lack the muscle mass or strength in the supportive structures (ligaments, bones) required to perform certain physical tasks, and if they overexert or overuse the available muscle mass or supportive structures. Studies in basic combat training show that both high and low BMI increases injury risk. However, studies among active duty Soldiers only show that injury risk increases as BMI increases, possibly because very few active duty Soldiers have very low BMI (i.e., less than 18 kg/m^2).

KEYWORDS: *body mass index; physical fitness; injury prevention*

Introduction

This is the second of a two-part series discussing the association between physical fitness and injuries in military operations. Part 1 defined physical fitness, described how the concept was developed, and described the association between injury and aerobic fitness and muscular endurance.[1] Part 2 focuses on associations between injuries and flexibility, stretching, warm-up, and body composition.

Injuries, Flexibility, and Stretching

Flexibility is associated with injury, but the relationship is not what you might expect: either too much or too little flexibility can increase injury risk. Let us look at some data to better understand this. In one study,[2] US Army basic trainees were tested for hamstring flexibility prior to basic combat training (BT), and their injuries were tracked while they were in BT. Recruits were separated into quintiles of flexibility, meaning that each group (quintile [Q]) represented 20% of all the recruits in the study. The lowest risk was among those in the middle quintile (Q3) and injury risk was highest among those who had the most (Q5) or the least (Q1) flexibility (Figure 1A). Another study[3] looked at 423 Navy Sea, Air, and Land (SEAL) candidates training at the Basic Underwater Demolition/SEAL School near Coronado, California. Prior to training, the flexibility of their ankles was tested and their injuries were recorded while they were in SEAL school. The candidates were separated into tertiles, meaning that each group (tertile [T]) represented 33% of all candidates. The candidates with the most (T1) and least (T3) flexibility had the higher injury risk, while the group in the middle (T3) had the lowest injury risk (Figure 1B).

Flexibility can be improved by static stretching,[4,5] and, many years ago, stretching prior to physical activity was recommended to reduce the likelihood of injury.[6] However, this idea had not been tested experimentally at the time. A 1993 study[7] conducted in Amsterdam, The Netherlands, 421 male runners were placed into two groups—one group performed static stretching of

Figure 1 *Associations between flexibility and injuries.* **(A)** *Recruits in US Army Infantry One-Station Unit Training.* **(B)** *SEAL candidates.*

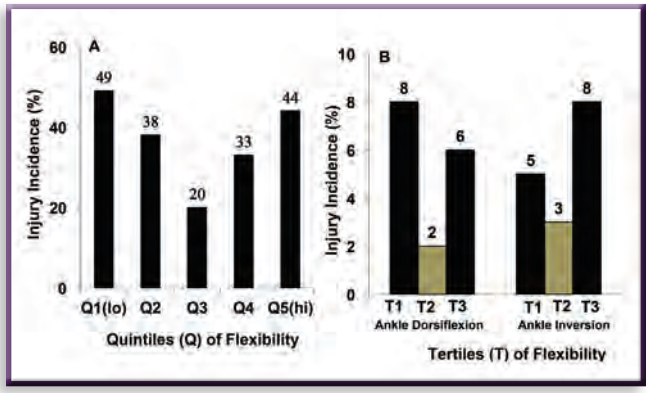
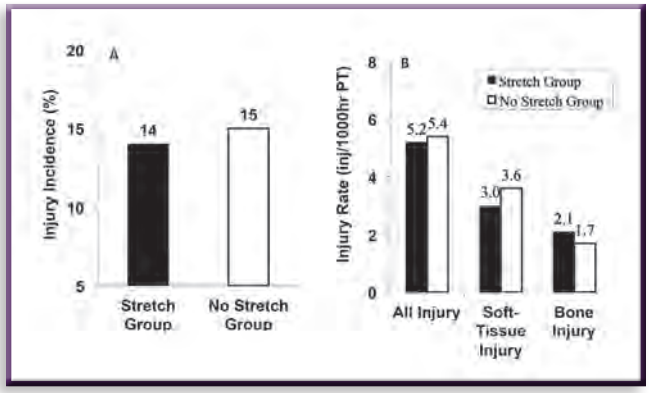


Figure 2 *Associations between stretching and injuries.* **(A)** *Runners.* **(B)** *Recruits in Australian Basic Training. PT, physical training.*



the lower body prior to running, and one group did not perform any stretching. The group that stretched received training in proper stretching techniques before the study began. After 16 weeks of training, the injury incidence in the two groups was almost identical and there were no significant difference between the groups (Figure 2A). Another study[8] was conducted among 1,538 male recruits in Australian basic training that were separated into two groups. One group performed one 20-second static stretch for six major leg muscles prior to physical training, while the other group did not perform any stretching. The data were calculated based on the number of injuries per 1,000 hours of physical training. There was no significant difference between the two groups whether the authors looked at all injuries, soft tissue injuries, or bone injuries (Figure 2B). It may appear that soft-tissue injuries were somewhat reduced in the group that stretched; however, it can be calculated that with a difference of the size seen in Figure 2B, and assuming 1-hour physical training sessions, a recruit would need to stretch for 1,666 sessions to prevent one injury of this type. Another study, with the Japan Ground Self-Defense Force, found that stretching had no effect on overall injury incidence but might reduce muscle/tendon injury.[9] Literature reviews of studies on static stretching have generally concluded that stretching prior to exercise does not reduce the overall incidence of injuries, but further research is needed on examining particular types of injuries, like muscle strains.[5,10]

Besides the futility of stretching to prevent injuries, it appears that stretching may be detrimental for some types of performances. Meta-analysis is a statistical technique that allows data from multiple studies to be combined to more adequately determine how large a particular effect might be. A recent meta-analysis[11] examined 104 studies that looked at the effect of pre-exercise stretching on maximal strength and power (the authors called the latter "explosive strength"). Static stretching prior to activity reduced performance on both strength and power tasks regardless of age, sex, or training status. Smaller negative effects were noted with shorter periods of stretching.

It would appear that either too much or too little flexibility is associated with higher injury risk and that static stretching has little effect on overall injury risk. In studies where all participants perform stretching, there will likely be a variety of "natural" flexibilities (i.e., flexibilities before stretching) ranging from low to high. Those with low flexibility will increase their flexibility with stretching. This may be equivalent to moving from Q1 to Q2 or Q3 in Figure 1A. Those who are more flexible will also further increase their flexibility and may move from Q4 to Q5, or even off the chart. It may be that individuals with low flexibility need to be identified and provided stretching exercises, while those who are highly flexible do not need to stretch. We do not really know at this point, but studies conducted along these lines could test this hypothesis. Currently, the data suggests that when large groups of individuals perform static stretching the overall risk of injury does not change compared to no stretching at all. Further, acute stretching may be detrimental to activities involving strength and power. Soldiers should keep in mind that flexibility is a component of physical fitness[1] and that stretching does increase flexibility.[4,5] Just because static stretching has little effect on overall injury risk does not mean that it should not be performed at all. Stretching may be included at the end of an exercise period when the body is warmed up from the activity. Those who are very flexible may not need to stretch, but more research is needed on this. It is only acute stretching that affects strength and power and so stretching at the end of an exercise bout should not affect later activities unless those activities are performed immediately after exercise. Currently, stretching after exercise is recommended in the Army's Physical Readiness Training Program.[12]

Injuries and Warm-up

Active warm-up uses low-intensity activity to increase muscle temperature and allow a gradual transition into more intense activity. There are two types of active warm-up—general and specific. General warm-up uses activities like low-intensity running, cycling, jumping, or lifting; specific warm-up uses activities similar to the exercises or sport that the individual is preparing for. It has been hypothesized that there are many favorable physiologic effects from active warm-up. These include reductions in muscle viscosity that may increase the speed and force of muscle contractions; increase the speed of nerve transmission, which could improve reaction time; more rapid dissociation of oxygen from hemoglobin, thus providing oxygen more rapidly to working muscles; and vasodilation, which increases blood flow in active tissues.[13,14] In experimental studies, more force and greater muscle length were required to tear rabbit muscles that had been prewarmed.[15,16] No military studies have examined the effects of warm-up on injuries, but a number of studies on athletes have shown that general and sports-specific warm-up routines appear to reduce the incidence of sports-related injuries.[17–20]

Injuries and Body Composition

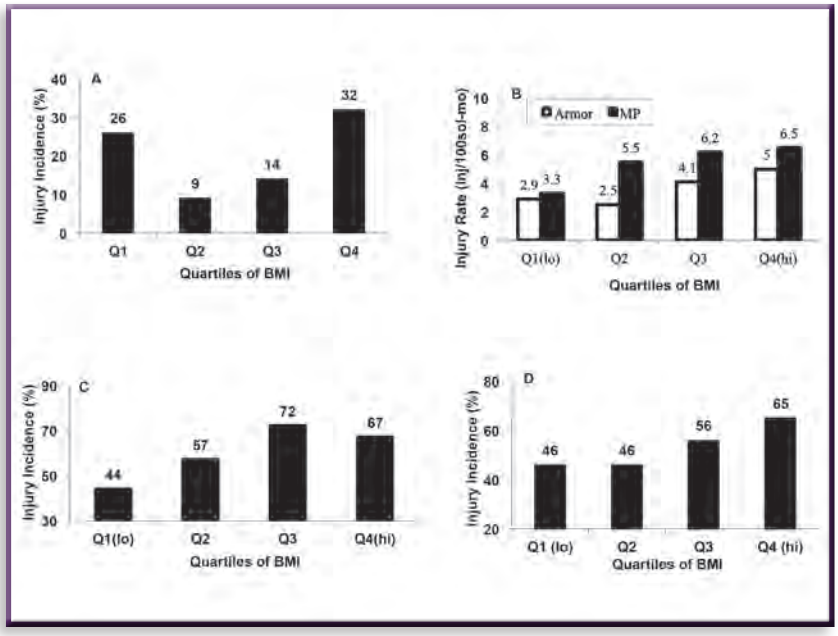
Studies that have looked at the relationship between body fat and body composition have generally looked at body mass index (BMI) as a surrogate measure for body fat. BMI is calculated as body weight divided by the square of height (kg/m^2).

Generally, BMI shows a close relationship with body fat in both military and civilian groups.[21–23] However, the relationship between BMI and injury is likely to be complex because individuals can have a high BMI either because of higher body fat or because of higher muscle and bone mass. If high BMI reflects a larger percentage of body fat relative to height, injury risk might be increased because the fat burden would (1) increase the intensity of physical activity,[24] leading to more rapid fatigue; and (2) impose additional repetitive stress on the musculoskeletal system because of the greater weight relative to height. In contrast to high BMI, low BMI may reflect a paucity of either fat or muscle/bone mass, or both. Low BMI may make Soldiers more susceptible to injury if they lack the muscle mass or strength in the supportive structures (ligaments, bones) required to perform certain physical tasks and/or if they overexert or overuse the available muscle mass or supportive structures, possibly leading to acute or overuse injuries, respectively.

Studies in BT generally have a sufficient number of recruits with both low and high BMI to show that either extreme will increase injury risk. Figure 3A shows the results of a study that looked at this relationship among male recruits in US Army BT.[25] Recruits with either low or high BMI showed higher risk of injury than those with BMI in the two middle quartiles (a quartile is 25% of all recruits tested). The National Institutes of Health considers individuals with "low" BMI to have a BMI value less than 18.5 kg/m^2. Data from several military occupational specialties (MOS) (Figure 3B–D) indicate that, generally, the higher the BMI, the higher the injury risk.[26,27] The inability of these MOS studies to show that lower BMI increases injury risk may be because very few active duty Soldiers have a BMI less than 18.5 kg/m^2. Future studies are needed to examine associations between low BMI and injury risk in active duty Soldiers.

In summary, studies generally suggest that static stretching will not reduce the incidence of injury but that warm-up activities may be beneficial. Soldiers should maintain their BMI in the normal weight range, which the National Heart, Lung, and Blood Institute has defined as 19–25 kg/m^2.[28] Among Soldiers with a muscular build, BMI is likely to overestimate the amount of fat. Soldiers need to develop and maintain a high level of physical fitness and optimal body composition not only

Figure 3 *Associations between BMI and injury.* **(A)** *Recruits in US Army Basic Combat Training.* **(B)** *US Army Armor Soldiers and MP.* **(C)** *US Army Wheel Vehicle Mechanics.* **(D)** *US Army Band. BMI, body mass index; MP, military police; sol-mo, Soldier-months.*



for peak performance of occupational tasks but also to reduce injury risk. Recommendations and guidance for physical training is contained in *Army Physical Readiness Training* (Field Manual 7-22).[12]

Acknowledgments

Thanks to Mr. Keith Hauret for the unpublished data in Figure 3B. Mr Ryan Steelman edited the article and provided comments.

Disclaimer

The views expressed in this presentation are those of the author(s) and do not necessarily reflect the official policy of the Department of Defense, Department of the Army, US Army Medical Department, or the US Government.

Disclosure

The author has nothing to disclose.

References

1. **Knapik JJ.** The importance of physical fitness for injury prevention (part 1). *J Spec Oper Med*. 2015;15:123–127.
2. **Jones BH, Cowan DN, Tomlinson JP, et al.** Epidemiology of injuries associated with physical training among young men in the Army. *Med Sci Sports Exerc*. 1993;25:197–203.
3. **Kaufman KR, Brodine SK, Shaffer RA, et al.** The effect of foot structure and range of motion on musculoskeletal overuse injury. *Am J Sports Med*. 1999;27:585–593.
4. **Beltrao NB, Ritti-Dias RM, Pitanqui AC, et al.** Correlation between acute and short-term changes in flexibility using two stretching techniques. *Int J Sports Med*. 2014;35:1151–1154.
5. **McHugh MP, Cosgrave CH.** To stretch or not to stretch: the role of stretching in injury prevention and performance. *Scand J Med Sci Sports*. 2010;20:169–181.
6. **Mathews DK.** *Measurement in Physical Education*. Philadelphia, PA: WB Sanders Co.; 1968.
7. **VanMechelen W, Hlobil H, Kemper HCG, et al.** Prevention of running injuries by warm-up, cool down, and stretching exercises. *Am J Sports Med*. 1993;21:711–719.
8. **Pope RP, Herbert RD, Kirwan JD, et al.** A randomized trial of preexercise stretching for prevention of lower-limb injury. *Med Sci Sports Exerc*. 2000;32:271–277.
9. **Amako M, Oda T, Masuoka K, et al.** Effect of static stretching on prevention of injuries for military recruits. *Mil Med*. 2003;168:442–446.
10. **Thacker SB, Gilcrest J, Stroup DF, et al.** The impact of stretching on sports injury risk: a systematic review of the literature. *Med Sci Sports Exerc*. 2004;36:371–378.
11. **Simic L, Sarabon N, Markovic G.** Does per-exercise static stretching inhibit maximal muscular performance? A meta-analytical review. *Scand J Med Sci Sports*. 2013;23:131–148.
12. *Army Physical Readiness Training, Field Manual 7-22*. Washington DC: Headquarters, Department of the Army; 2012.
13. **Shellock FG, Prentice WE.** Warm-up and stretching for improving physical performance and prevention of sports related injuries. *Sports Med*. 1985;2:267–278.
14. **Woods K, Bishop P, Jones E.** Warm-up and stretching in the prevention of muscular injury. *Sports Med*. 2007;37:1089–1099.
15. **Safran MR, Garrett WE, Seaber AV, et al.** The role of warmup in muscular injury prevention. *Am J Sports Med*. 1988;16:123–129.
16. **Strickler T, Malone T, Garrett WE.** The effect of passive warming on muscle injury. *Am J Sports Med*. 1990;18:141–145.
17. **Gilchrist J, Mandelbaum BR, Melancon H, et al.** A randomized controlled trial to prevent noncontact anterior cruciate ligament injuries in female collegiate soccer players. *Am J Sports Med*. 2008;36:1476–1483.
18. **Groom DR, Palmer T, Onate JA, et al.** Soccer specific warm-up and lower extremity injury rates in collegiate male soccer players. *J Athl Train*. 2013;48:782–789.
19. **Olsen OE, Myklebust G, Engebretsen L, et al.** Exercises to prevent lower limb injuries in youth sports: cluster randomized controlled trial. *Br Med J*. 2005;330:449–456.
20. **Soligard T, Myklebust G, Steffen K, et al.** Comprehensive warm-up programme to prevent injuries in young female footballers: cluster randomized controlled trial. *Br Med J*. 2008;337:a2469.
21. **Knapik JJ, Burse RL, Vogel JA.** Height, weight, percent body fat and indices of adiposity for young men and women entering the U.S. Army. *Aviat Space Environ Med*. 1983;54:223–231.
22. **Knapik JJ, Jones SB, Sharp MA, et al.** *A prospective study of injuries and injury risk factors among United States Army wheel vehicle mechanics*. Technical Report No. 2-MA-7193 B-06. Aberdeen Proving Ground, MD: US Army Center for Health Promotion and Preventive Medicine; 2006.
23. **Roche AF, Siervogel RM, Chumlea WM, et al.** Grading body fatness from limited anthropometric data. *Am J Clin Nutr*. 1981;34:2831–2838.
24. **Cureton KJ.** *Effects of experimental alterations in excess weight on physiological responses to exercise and physical performance*. In: Marriott BM, Grumstrup-Scott J, eds. *Body Composition and Physical Performance Applications for Military Services*. Washington, DC: National Academies Press; 1992.
25. **Jones BH, Bovee MW, Harris JM, et al.** Intrinsic risk factors for exercise-related injuries among male and female Army trainees. *Am J Sports Med*. 1983;21:705–710.
26. **Knapik JJ, Jones SB, Darakjy S, et al.** Injury rates and injury risk factors among United States Army Wheel Vehicle Mechanics. *Mil Med*. 2007;172:988–996.
27. **Knapik JJ, Jones SB, Darakjy S, et al.** Injuries and injury risk factors among members of the United States Army Band. *Am J Ind Med*. 2007;50:951–961.
28. "Calculate your body mass." https://www.nhlbi.nih.gov/health/educational/lose_wt/BMI/bmicalc.htm.

MAJ (Ret) Knapik served as an enlisted wheel vehicle mechanic and medic before he was commissioned as a Medical Service Corps officer. He retired from military service in 1994 and continued active research at the US Army Research Laboratory and epidemiology at the Army Institute of Public Health before retiring from civil service in 2011. He is a fellow of the American College of Sports Medicine and holds the Order of Military Medical Merit. He is currently working as a Knowledge Preservation Fellow at the Oak Ridge Institute for Science and Education. E-mail: joseph.j.knapik@JSOMonline.org.