Maximizing Competition Performance: The Warm-up and Post Activation Potentiation

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A dynamic warm-up specific to the sport or activity, is often an integral part of any pre-activity protocol. The warm-up prepares the athlete for practice or competition and may decrease the risk of injury

Why is this Important?

- In the last 2 Olympics, the difference between first and fourth place (for most
- sports) was less than 1.5 %.

Introduction

- A well-designed warm-up will bring about various physiological changes that will enhance the training activity or competition.
- Although the need for a warm-up might be clear.
  - The specific elements may be less obvious.
- There are basically two forms of stretching employed on a regular basis among athletes; acute stretching as part of the warm-up process and chronic stretching that is often quite extensive, and occurs after a training session.

Pre-Activity Preparation

- A well-designed strength and conditioning program includes strategies devoted to preparing the athlete for an activity.
- The literature dealing with flexibility suggests that athletes should perform some sort of 'general' warm-up (prior to activity) and post-activity stretching.

Commonly Held Beliefs

- Acute stretching prior to practice or competition may:
  - Increase performance
  - Reduce potential of injury
- Chronic stretching following practice or competition may:
  - Increase performance
  - Reduce aches and pains and reduce potential of injury

History

- Research as far back as the 1950s and 1960s showed that a pre-activity warm-up could be beneficial to vertical jump performance.
- Anderson (1980) built on this idea by stating that some sort of general warm-up should be conducted before any other type of activity.
- Specifically, he suggested that a light jog of 200 to 400 yards be performed, followed by static stretching.

The Warm-up

- Hedrick (1992) pointed out several physiological responses to a warm-up activity that have a direct relation to improved performance.
- The first response was the friction between the contractile filaments during the contraction of muscles.
- This friction resulted in an increase of tissue temperature within the body, aiding the body's need to increase circulation for the raised oxygen requirements.
- Yet another physiological benefit of a pre-activity warm-up is that it can decrease the occurrence of abnormal electrocardiogram responses at the onset of activity.

The Warm-up

- Ninos (1995) suggested that 5 to 10 minutes of easy, low-level aerobic activity, such as cycling or jogging, should be performed before stretching.
- He claimed that the best way to know the body's internal temperature has been raised is the onset of perspiration.

Advantages of the Warm-up

- Mann and Jones (1999) pointed out that many athletes who begin activities without some sort of warm-up will have muscles that are at a minimal core temperature, and therefore, are not properly prepared for activity.
- For each degree that the athlete raises the core temperature of the muscle, about 13 percent efficiency is gained.
- If the body is not prepared for the activity, the threat of injury may in fact be at a higher level.

Pre-Activity Flexibility

- Research pertaining to pre-activity warm-up and stretching and post-activity stretching has evolved over the past few decades.
- The second pre-activity debate involves what type of stretching is performed (if performed at all) prior to activity.
- Current research shows that some of the activities suggested a few decades ago are no longer suggested practice.

Ballistic and PNF Stretching

- The ballistic-style of stretching popular in the 1960s was slowly replaced in the early 1980s with a focus on static and/or PNF stretching
- Cornelius (1984) favored PNF stretching over ballistic stretching, stating that the explosive nature of ballistic stretching created a higher risk for injury and can cause soreness.
- PNF stretching, he concluded, will result in greater flexibility.

Static Stretching

- The pre-activity stretching routine suggested by Anderson (1980) contained a variety of static stretching for the groin, hips, ankles, and lower back.
- These types of stretches before activity would allow the muscles the opportunity to move freely and easily.
- Wallace (1984) also preferred this static type of stretching due to its ability to produce plastic changes in the muscle-tendon unit.
- Beaulieu (1984) also favored static stretching, but also points out that no one stretching technique, at that time, had been shown to be more effective than the others.

Impact of Pre-Activity Static Stretching

- As suggested by Prentice (1984), the current trend has found that these static and/or PNF stretching tactics are better suited following activity, not before it.
- Several other studies have shown that using static stretching as a pre-activity warm-up has no effect on performance.
- Nelson, Kokkonen, and Arnall (2005) found that static stretching actually lowered the muscular strength endurance in 22 college students by 28 percent.
- Another study on adults aged 18 to 34 years found vertical jump performance to be 5.6 percent lower following static stretching as compared to no stretching at all.
- A similar study (Unick, Kieffer, Cheesman, and Feeney, 2005) found no difference in vertical-jump performance from either static or ballistic stretching as compared with no stretching.
- One final study by Cramer (2004) found no effect on peak torque of leg extensors from static stretching.

The Effects of Acute Stretching (Warm-Up) on Performance Variables

Performance	Study	Result
Sprinting	Nelson et al. (2005) McBride et al. (2004)	Decrease Decrease
Standing Long Jump	Koch et al. (2003)	ND
Counter Movement Jump	Cornwell et al. (2001) Knudson et al. (2001) Michael and Sanos (2003)	Decrease ND Decrease
Static Jump	Young et al. (2003) Cornwell et al. (2001)	Decrease ND
Dynamic Strength	Fry et al. (2003) Kokkonen et al. (1998)	Decrease Decrease
Isometric Strength	Nelson et al. (2005) Behm et al. (2001) Avela et al. (1999)	Decrease Decrease Decrease
Strength Endurance	Nelson et al. (2005) Nelson et al. (2001)	Decrease Decrease
Summary: Explosive performance can be compromised by static stretching. ND= No Difference (Adapted from Rees, 2006)		

Transition to Dynamic Flexibility

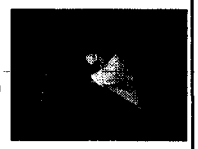
- Mann and Jones (1999) state that types of dynamic warm-up routines are designed "from analyzing the movements associated with a particular sports activity and developing stretches to enhance flexibility and balance for that activity".
- They explained that most static stretches can be easily transformed into dynamic stretching.
- For example, instead of having an athlete push against a wall with his leg stretched behind him in order to stretch the calf, have him walk on the balls of his feet for 10 yards, both forward and backward.
- Static stretching does very little to raise the internal temperature of the muscle, but having the athlete perform a dynamic movement can help to raise the core temperature.

Dynamic Warm-up

- Yamaguchi and Ishii (2005) found dynamic stretching to be better than static stretching or no stretching at all for leg extension power in male students.
- In another study, athletes were tested on a t-test, underhand medicine-ball toss, and a five-step jump test.
- Their results were significantly greater when dynamic stretching was performed prior to the tests than when static stretching was performed.
- Little and Williams (2006) also found agility performance to be greater following dynamic stretching as opposed to static. This research suggests that dynamic stretching should be included as part of a warm-up.

Pre-Activity Stretching

- Most of the performance studies indicates that acute stretching as a part of warm-up reduces maximum strength (force magnitude) and several associated variables, such as rate of force development and power output (Behm, 2001; Godges, 1989; Nelson, 2001; Rosembaum, 1995).



Pre-Activity Static Stretching

- Additionally, a decreased H-reflex has been noted (Avela, 1999; Avela, 1998; Guissard et. al, 2004)
- The H-reflex is a monosynaptic reflex elicited by stimulating a nerve, particularly the tibial nerve, with an electric shock.
- Thus, it appears that stretching acutely as part of a warm-up can negatively alter force production, power output, and stretch-shortening cycle characteristics such that strength and performance, including explosive performances, can be compromised

Post-Activity Flexibility

- The final research recommendation indicates that athletes should perform static-style stretching following exercise (Anderson, 1984; Egan, 2006; Nelson, 2008; Stone, 2006; Swanson, 2008).

Table 1
Effects of Chronic (Weeks) Stretching on Performance

Study	Subject Description	Result
Positive effect		
Dinsman (1964)	Trained (n=145, 4 groups	Faster running speed*
Handel et al (1997)	Various Athletes	Increased force
Kerrigan et al (2003)	Elderly (n= 47E, 48C	Improved gait
Wilson et al (1992)	Powerlifters (n = 9E 7C	Enhanced stretch-shortening cycle
Hunter and Marshall (1995)	Various Athletes (n = 60, 3 groups	Improved vertical jump
Worrell et al. (1994)	Active Students (n = 16)	Increased hamstring force
Hortobagyi et al. (1996)	Active Students (n = 12)	Increased knee extension force
No effect		
Nelson et al (2005)	Physically Active	No effect running performance
Godges et al (1989)	Physically Active	No effect on gait economy

*Augmented strength + spring training, E = experimental, C = control (Adapted from Stone, 2006)

Does Flexibility Work Prevent Injuries

- Most studies indicate that reduced flexibility shows little relationship to typical sports injuries.
- Neither acute (Pope, 2000) nor chronic (Herbert, 2002) stretching appears to effect a significant reduction in physical activity related injuries.

Preventing Injury

- Thacker et al. (2004), in an extensive review of the flexibility literature that included 361 articles dating back into the 1950s, concluded that there is little relationship between stretching (e.g., increased ROM) and injury.
- Thus, there is little evidence that stretching and improved ROM effects a lower injury rate.

Table 2
Potential Injury Reducer

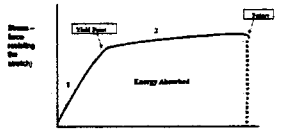
Injury and Rate of Motion		(Shrier, 2004)
Study	Injury site	Result
Nadrees et al. (1989)	Lumbar spine	No relation
Zuberer (2001)	Low back	No relation
Emery and Meeuwisse (2001)	Groin (hockey	No relation
Wesson (2001)	Soccer injuries	No relation
Some Determinates of Injury		
Study	Variables	Result
Stewart and Burden (2004)	Extreme rate of motion	Increased injury risk
Kornelsen Voight (2002)	Excessive rate of motion/ poor stability	Increased injury risk
Orchard (2001, 1997)	Previous injury or defect	Increased injury risk
Emery and Meeuwisse (2001)	Previous injury	Increased injury risk
Orchard (2001, 1997)	Fatigue	Increased injury risk
Akrolos et al. (1999)	Volume of training/fatigue	Increased risk potential
Yamamoto (1993)	Relative Strength	Decreased injury risk
McCarthy et al. (1999)	Strength	Decreased injury risk
Orchard et al. (1997)	Strength	Decreased injury risk
Nadler et al. (2000)	Strength	Decreased injury risk
Craven et al (2002)	Strength (eccentric)	Decreased injury risk

Mechanisms of Acute Stretching

- There are basically 2 mechanistic possibilities that may have an effect individually or in combination:
- (a) stretching alters ROM by altering the structure and properties of soft tissue (muscle and connective tissue);
- (b) there is an increase in pain tolerance (Stone, 2006).

Tissue Stiffness

- Tissue stiffness is the ability of a tissue to resist change in length and is represented by a change in force per change in length ($\Delta F/\Delta L$).
- A decreased or increased stiffness may alter the stress strain curve (changes in force when muscle or connective tissue is lengthened or shortened by stretching).
- The stiffer the tissue, the more it resists the stretch, and there are 2 possible results:
  - (a) the rate at which force rises is faster;
  - (b) the failure point of the tissue may be reached faster.



Strain - Lengthening

A force-length or stress-strain curve. 1 = elastic region; region of stretch in which the elastic properties of the tissue increase the force by resisting (pulling back against the stretch). 2 = non-elastic region; region of stretch in which the elastic properties of the muscle are stretched to their limit and Non-elastic elements resist the stretch.

Muscle Stiffness

- Muscle can also be activated to resist a stretching load (e.g., eccentric contractions).
- Thus, muscle tissue has active stiffness properties.
- Contraction during stretching can take up the slack in the exercise reducing tissue stiffness could enhance flexibility
- However, in the normal intact human, changes in the length of a muscle (or muscles) also alter the feedback to the nervous system.
- For example, a less stiff muscle would produce less force at a given length, and the nervous system senses this difference
- Thus, alterations in muscle stiffness (active or passive) could change how the nervous system reacts to a given muscle length.

Relationship Muscle Stiffness and Performance

Increased ROM (decreased passive stiffness)
(Avela et al 2004)

Increased Passive Stiffness – greater elastic storage
(greater running economy)

Increased distance running performance
(Spurrs et al. 2003)
(Craib et al 1996)

Increased Active and Passive Stiffness-
Increased Power Output (Jumping)
(Arampatzis et al. 2001)

Stiffness ↑ Performance ↓

Stiffness ↓ Performance ↑

Muscle Stiffness and Strength

- Interestingly, maximum strength and strength training effects appear to be associated with increased active and passive muscle stiffness that is independent of ROM alterations (Gleim, 1997; Kubo, 2001; MacPherson, 1996; Salsich, 1996)
- An increase in muscle stiffness appears to be associated with enhanced strength (1991) and various types of performances, including the vertical jump and improved running (i.e., enhance running economy; Figure 2)
- Thus, a loss of performance associated with acute stretching could be associated with a decrease in muscle stiffness.

High Intensity Warm-up Activities

- In an activity like throwing, which requires explosive strength, performance factors that should be addressed during the warm-up include optimal stiffness of the series elastic component and rapid activation of the contractile apparatus (Chiu, 2003).

High Intensity Warm-up

- Postactivation potentiation (PAP) is the increase in muscle force and rate of force development as a result of previous activation of the muscle.
- The implementation of high-intensity contractions as a component of the warm-up prior to a training session or a competition has been suggested to improve performance.

What is PAP?

- The contractile history of a muscle influences the mechanical performance of subsequent muscle contractions.
- Fatiguing muscle contractions impair muscle performance; whereas, non-fatiguing muscle contractions, typically at high loads of brief duration, may enhance muscle performance.

Introduction

- Although the idea of post contraction potentiation is not new, the use of strength-power potentiating complexes (SPPC) or complex pairs has been the focus of a great deal of recent discussion and study (Stone, 2008).

What is Considered a SPPC?

- A SPPC involves the performance of a high force (Guellich, 1996) or high power (Radcliff, 1996) movement in order to potentiate a subsequent high power or high velocity movement.

Examples of SPPC's

- Olympic weightlifting exercises, squats, jump squats, heavy medicine-ball throws, and throws with heavy implements are activities that could be used as part of the warm-up.

Examples of SPPC's

- Example, heavy squats may potentiate subsequent vertical jumps or sprinting performance
- The use of these SPPCs could be useful as a training method or as an acute performance enhancing factor immediately pre-competition

Contrast Training

Do SPPC's Work?

- The use of these SPPCs has, in some cases, (Duthie, 2002; Guellich, 1996; Young, 1998), but not all (Gossen, 2000; Hrysomallis, 2001) been shown to acutely increase performance.

Importance of Fitness

- Young et al. (1998) and Duthie et al.(2002) have suggested that there is a relationship between strength and PAP, specifically, that stronger, better-trained athletes may be better equipped to benefit from PAP

Optimal Time Period

- The specifics of the conditioning or warm-up contractions still need to be addressed, if we are to better understand the practical applicability of PAP for enhancing athletic performance (Robbins, 2005).
- There is one report that documents PAP and improvement in jump squat performance from 5 to 18.5 minutes following a heavy-load warm-up in power-trained athletes without a concomitant effect in recreationally trained individuals (Chiu, 2003).

A theoretical foundation for a SPPC can be found in the Fitness-Fatigue concept

- This theory suggests that as a result of training both "fitness" and "fatigue" characteristics are accumulated
- This "accumulation" is related to the volume and intensity of training.
- Fatigue masks the ability to manifest the effects of fitness, thus as long as fatigue remains high; the potential to perform (i.e. Preparedness) is suppressed.
- If volume is decreased then fitness and fatigue become "after-effects" of training that begin to diminish in magnitude.
- However, fatigue decreases at a faster rate than does fitness; thus at some point preparedness reaches a peak relative to fatigue.
- If fitness falls off too much (e.g. taper for too long) then preparedness (and performance) also declines.
- In terms of performance, this theoretical concept can be viewed as a long-term factor or an acute factor.

Mechanism of PAP

- From an acute standpoint, conceptually the potentiating exercise raises the "fitness" level of the athlete as well as fatigue.
- Increased "fitness" arises from the stimulation/alteration of specific underlying mechanisms within the neuromuscular system.
- At the termination of the potentiating exercise, fitness and fatigue again can be viewed as after-effects; the rate of decay of these after-effects again determines the level of "preparedness" and potential performance – in this case, in the short-term.

Factors Affecting Potentiation

- Three factors that may affect the degree of potentiation are initial strength levels (Chiu, 2003, Duthie, 1990) the current level of fatigue (Sale, 2002) and past training experience (Hamada, 2000).
- Stronger athletes appear to produce potentiation effects to a greater degree (or more often) than weaker athletes.

Importance of Strength

- Evidence indicates that training background and maximum strength level are related to the capability for potentiation (Sale, 2002; Young, 1998).

Field Data

Erin Gilreath	20 lb Weight	2004 Gator Inv.	78'7"	World Record
Erin Gilreath	Hammer	2004 Sun Angel Classic	72.12m	American Record

Field Data

Candice Scott	20 lb Weight	2005 SEC	78'5	Collegiate Record
Candice Scott	20 lb Weight	2005 NCAA	76'2"	NCAA Meet Record

Field Data

Candice Scott	Hammer	2003 NCAA	69.85	Collegiate Record
Candice Scott	Hammer	2005 All Comers Meet	71.45	National Record
Candice Scott	Hammer	2005 WC	66.84	9th WC

Conclusions

- It appears that some coaches continue to adopt warm-up flexibility practices based on tradition despite contradictory information in the literature.
- The research indicates that it is important for strength coaches to re-evaluate their own practices, perhaps cross-checking them with the practices of their peers and the available research.
- As the knowledge base for stretching and warm-up strategies continues to evolve, coaches should evolve with them to ensure their athletes are being tended to with the best available treatment and care.
- Coaches need to devise a pre activity warm-up routine based primarily on data driven research and not be reluctant to change "traditional" methods.

Questions??