EFFECTIVENESS OF PRE-EXERCISE STRETCHING ON A JUDO FITNESS TEST

A Thesis

Presented to the faculty of the department of Kinesiology
California State University, Sacramento

Submitted in partial satisfaction of the requirements for the degree of

MASTER OF SCIENCE

in

Kinesiology
Exercise Science

by
Kelsey Ann Hammerel

SPRING 2012
EFFECTIVENESS OF PRE-EXERCISE STRETCHING ON A JUDO FITNESS TEST

A Thesis

by

Kelsey Ann Hammerel

Approved by:

______________________________, Committee Chair
Daryl Parker, Ph.D.

______________________________, Second Reader
Rodney Imamura, Ph.D.

______________________________
Date
Student:  Kelsey Ann Hammerel

I certify that this student has met the requirements for format contained in the University format manual, and that this thesis is suitable for shelving in the Library and credit is to be awarded for the thesis.

__________________________, Graduate Coordinator
Michael Wright, Ph.D.  ____________________________

Date

Department of Kinesiology
Abstract

of

THE EFFECTIVENESS OF PRE-EXERCISE STRETCHING ON A JUDO FITNESS TEST

by

Kelsey Ann Hammerel

Introduction

Acute static stretching has been shown to cause detrimental effects on athletic performance (McHugh & Cosgrove, 2010; Shrier, 2004). Judo, a descendent of jujitsu, usually incorporates a period of stretching into the warm-up before physical activity (Callister et al., 1991). It is unknown whether static stretching is superior to a dynamic or a judo specific warm-up. Therefore, the purpose of this study was to investigate the effects of three stretching protocols over 4 weeks prior to performing a Special Judo Fitness Test (SJFT).

Methods

Eight healthy judo athletes volunteered for this study, all holding brown or black belts. Athletes attended 1 familiarization and 3 data collection sessions over 7 weeks where judoists performed the stretching protocols and completed the SJFT. Statistical comparisons were made between heart rate and number of throws on the test to determine the fitness levels as well as performance with stretching.
Results

No statistical significances were found between warm-ups, heart rate, and throws; although there was a significant downward trend in the fitness index for static stretching. The decrease in index score with static stretching indicated better performance. The main effect for warm-up on index score was \( p=0.06 \). The main effect for heart rate on time was significant throughout the test, with \( p=0.0000 \). The main effect for number of throws per round was also significant throughout the test, \( p=0.0000 \), with no interaction effects for any of the variables tested.

Conclusion

Recently, static stretching has received negative attention from researchers regarding performance and stretch-induced impairments. A majority of studies find equivocal results with respect to intensity, frequency, and duration of stretch. The current hypotheses were not supported, and encourage the use of static stretching pre-exercise. Although more research is needed in this area of study, martial arts populations may still benefit from the use of static stretching prior to competition. Other stretching recommendations must be sport specific and tailored to individual needs in regard to muscular performance.

__________________________, Committee Chair
Daryl Parker, Ph.D.

__________________________
Date
ACKNOWLEDGEMENTS

First I’d like to thank the judo club members for volunteering their time to participate in this study, as well as my peers Grace Whang, Liz Darr, and Dan Wadleigh for assisting in this data collection. Although counting the number of throws, monitoring the stopwatch, and reading heart rate from a watch is not a difficult task, without your assistance testing would have been a prolonged task.

Secondly, I would like to thank my advisors Dr. Parker and Dr. Imamura for taking time out of their busy schedules to conduct and oversee this research. Without your genuine interest in stretching and judo performance my research would not have been possible. I appreciate your devotion to the study of exercise physiology as well as the well-being of your students.

Lastly, I would like to thank my parents; my supportive base to which I owe all of my continued knowledge to. Without your unconditional love and generous accommodations, my dreams of becoming a certified athletic trainer and Sacramento State Alumni would not have been possible.
TABLE OF CONTENTS

Page

Acknowledgements ........................................................................................................ vii
List of Tables .................................................................................................................. x
List of Figures ................................................................................................................ xi
Chapter
1. INTRODUCTION ....................................................................................................... 1
   Statement of Purpose ................................................................................................. 4
   Significance of Thesis ............................................................................................... 4
   Definition of Terms ................................................................................................. 6
   Delimitations ........................................................................................................... 9
   Limitations ............................................................................................................... 9
   Assumptions ........................................................................................................... 9
   Hypotheses ............................................................................................................ 9
2. REVIEW OF LITERATURE ....................................................................................... 10
   Deficits in Performance ........................................................................................... 14
   Neurological and Mechanical Mechanisms ......................................................... 16
   Intensity, Frequency, and Duration ......................................................................... 18
   Competitive Structure of Judo ............................................................................... 19
   Physiological Responses ......................................................................................... 22
   Fitness Testing of Judo Athletes ........................................................................... 24
   Summary ................................................................................................................. 26
3. METHODS .................................................................................................................. 27
   Subjects ................................................................................................................... 27
   Procedures .............................................................................................................. 28
   Heart Rate ............................................................................................................... 29
   Stretching Protocols ............................................................................................... 30
LIST OF TABLES

<table>
<thead>
<tr>
<th>Table</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Table 1</td>
<td>Subject characteristics</td>
<td>28</td>
</tr>
<tr>
<td>Table 2</td>
<td>Dynamic warm up</td>
<td>30</td>
</tr>
<tr>
<td>Table 3</td>
<td>Static stretching warm up</td>
<td>32</td>
</tr>
<tr>
<td>Table 4</td>
<td>Judo specific warm up</td>
<td>33</td>
</tr>
<tr>
<td>Table 5</td>
<td>SJFT index</td>
<td>37</td>
</tr>
</tbody>
</table>
## LIST OF FIGURES

<table>
<thead>
<tr>
<th>Figure</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Figure 1</td>
<td>Image of the ippon-seoi-nage technique</td>
<td>36</td>
</tr>
<tr>
<td>Figure 2</td>
<td>Mean values of heart rate (bpm): resting, post SJFT, 1-minute post fitness test</td>
<td>40</td>
</tr>
<tr>
<td>Figure 3</td>
<td>Throws per round (1-3) and total (4)</td>
<td>41</td>
</tr>
<tr>
<td>Figure 4</td>
<td>Main effect of warm-up for index scores</td>
<td>42</td>
</tr>
</tbody>
</table>
Chapter 1

INTRODUCTION

Stretching is an integral component of an athlete’s warm-up, commonly believed to increase sport performance and decrease the likelihood of injury. A traditional warm-up consists of submaximal aerobic activity designed to increase core temperature, followed by static stretching to achieve short-term increases in joint range of motion (ROM), and lastly sport specific movements to activate specific muscle and neural pathways (Young & Behm, 2002). Two of the more popular forms of stretching are static and dynamic. Static stretching, (SS) involves a controlled lengthening of a relaxed muscle (Mahieu, Mcnair, Muynck, Stevens, Blanckaert, Smits, Witvrouw, 2007). Dynamic stretching, (DS) uses active muscular effort to bring about stretch.

The necessity of the stretching component has become a prominent research question; especially regarding the intensity, frequency and duration of stretch. Stretching intensity is typically controlled by the subject’s level of discomfort (McHugh & Cosgrove, 2010). A duration of 15-30 seconds per muscle group is recommended for a warm-up, whereas longer protocols up to 1 hour (Avela, Krolainen, Komi, 1999) have reported increasingly negative effects. Acute static stretching has received negative attention in terms of performance in recreational athletes as well as trained individuals in sports including: soccer, track & field, basketball, and rugby.

Contrary to the notion that static stretching improves performance, research has demonstrated that stretching causes impairments in muscle force production (Ogura,
Miyahara, Naito, Katamoto, & Aoki, 2007; Brandenburg, 2006) short distance sprint times (Beckett, Schneiker, Wallman, Dawson, & Guelfi, 2009; Fletcher & Monte-Colombo, 2010; Sim, Dawson, Guelfi, Wallman, & Young, 2009; Chaouachi, Castagna, Chtara, Brughelli, Turki, Galy, Chamari, & Behm, 2010), change of direction performance (Beckett et al., 2009), vertical jump height (Young & Behm, 2003), endurance (Nelson, Kokkonen, & Arnall, 2005), peak torque (Siatras, Mittas, Mameletzi, & Vamvakoudis, 2008; Cramer, Housh, Weir, Johnson, Coburn, & Beck 2005; Evetovich, Nauman, Conley, & Todd, 2003; Herda, Cramer, Ryan, McHugh, & Stout, 2008), balance and reaction time (Behm, Bambury, Cahill, & Power, 2004), as well as decreases in strength ranging from 4.5% to 28% (Rubini, Costa, & Gomes, 2007; Fowles, Sale, & MacDougall, 2000; Ryan, Beck, Herda, Hull, Hartman, Stout, & Cramer, 2008; Bacurau, Monterio, Uhrinowotsch, Tricoli, Cabral, & Aoki, 2009). These deficits in performance variables have been shown to last approximately 60 minutes after completion of the stretching routine (Fowles et al., 2000).

Possible mechanisms for the stretched-induced deficits include mechanical and neurological changes. Neural adaptations to static stretching have been thought to cause a decrease in muscle activation and failure of excitation. The level at which nervous system disruption occurs is yet to be determined, but is still extensively researched (Fletcher & Monte-Colombo, 2010). The effect static stretching has on the nervous system can be observed by decreases in electromyography (EMG) signals. Authors who report these readings state that the elongation of muscle affects proprioception of the muscle spindles.
and golgi tendon organs (GTO) (Cè, Rampichini, Maggioni, Veicsteinas, & Merati, 2008). These sensors, located at the myotendinous junctions, detect high force as well as muscle lengthening and inhibit further contraction by the agonist muscles to prevent potential injuries (Fowles et al., 2000). Because it takes an extremely intense stretch to activate the GTO inhibition mechanism, more research is denoting mechanoreceptor (type III afferent) and nociceptor pain feedback (type IV afferent) to explain altered feedback.

Mechanical modifications have been thought to interrupt the muscletendinous unit (MTU) and cross bridges between actin and myosin filaments. This causes a more compliant MTU and requires more time to take up “slack” to initiate contraction. This delay in activity from the nervous system to the mechanical response of the muscle is known as electromechanical delay (EMD) (Wilson & Flanagan, 2008).

Many athletes are adopting more of a dynamic warm-up prior to physical activity due to its increase in core and muscle temperature, neuromuscular activity, and possible postactivation potentiation (Fletcher & Monte-Colombo, 2010). Postactivation potentiation (PAP) demonstrates the increase in muscle force production following a maximal contraction, due to increased sensitivity of the contractile proteins to calcium channels (Cè et al., 2008). Those athletes that still incorporate static stretching into daily warm-up routines should apply the stretches post activity to maintain range of motion benefits (Beedle, Leydig, & Carnucci, 2007).
Various tests have been developed to test the fitness of judokas, but do not comply with the principles of specificity, individuality and reproducibility (Santos, Gonzalez, Iscar, Brime, Fernandez-Rio, Egocheaga, Rodriguez, & Montoliu, 2010). The Special Judo Fitness Test (SJFT), developed by Sterkowicz (1995) is intermittent and uses specific judo movement patterns. It has been observed that efforts during a Wingate test as well as the SJFT are similar to the combat structure of a judo competition; and this test may serve as one of the criteria in the selection of individual exercises (Sterkowicz, Zuchowicz, & Kubica, 1999). Research evaluating the fitness of judoists should also consider warm-up routines commonly practiced. Because flexibility is an important component of the sport, various modes of stretching should be evaluated prior to activity.

Statement of Purpose

The purpose of this study was to investigate the effects of three different stretching warm-up protocols over 7 weeks on the Special Judo Fitness Test (SJFT) of judo competitors.

Significance of Thesis

To date, most research has only studied single repetition maximum voluntary contractions to mimic stretch-induced impairments in recreational active individuals; with very equivocal results regarding the mode of stretching that best prepares the body for movement. Very few studies have used sport specific drills or have actually used stretching durations and frequencies mimicking athletic warm-ups. Not only is there controversy regarding acute static stretching within an athlete’s warm-up, but a lack of
judo specific research on stretching prior to competition. This investigation is important to the field of exercise physiology, as the results indicate that static stretching may be useful prior to judo performance; and data from this research may be applicable to a variety of athletes.
**Definition of Terms**

1. **Aerobic energy system** - This system provides nearly all of the energy transfer when intense exercise continues beyond several minutes. This steady rate between energy required by working muscles and ATP production determines the capacity to sustain submaximal exercise (McArdle, 2009, pg. 165).

2. **Anaerobic energy system** - This system encompasses high-intensity exercise of short duration, which comes almost exclusively from the intramuscular high-energy phosphate sources, adenosine triphosphate (ATP) and phosphocreatine (PCr) (McArdle, 2009, pg. 163).

3. **Static stretch** - Static stretching usually involves moving a limb to the end of its range of motion (ROM) and holding the stretched position for 15–60 seconds (Young and Behm, 2002).

4. **Dynamic stretch** - A segment of skill rehearsal where the players would perform dynamic movements similar to the sport or event for which they were preparing (Young and Behm, 2002).

5. **Stretch-induced force deficit** - The transient reduction in force production after stretching (Costa, 2010).

6. **Electromyography (EMG)** - Amplitude values quantify muscle activation, which can be altered by the number of motor units recruited and the firing rates of the activated motor units. A neuromuscular measure, which provides amplitude values that can show
further insight regarding motor unit recruitment. The lateral oscillation produced by contacting muscles (Herda, 2008).

7. Electromechanical delay (EMD) - The time delay that exists from the onset of muscular activation to the onset of force development (Costa, 2010)

8. Golgi tendon organ (GTO) - Fine-tuned sensory receptors that detect differences in the tension generated by active muscle. These organs protect the muscle and surrounding connective tissue harness from injury from sudden or excessive load by transmitting signals to the spinal cord to elicit a reflex inhibition of the muscle they supply (McArdle, 2009, pg. 396).

9. Muscle spindle fibers- Sensory receptors within the muscle that are innervated by specialized afferent neurons; and when stretched, cause a number of reflex reactions (Wilson & Flanagan, 2008).

10. Postactivation potentiation (PAP) - PAP represents the increase in muscle force production subsequent to a submaximal or maximal contraction. The mechanism underlying this phenomenon is a higher rate of cross-bridges formation, consequent to an increased sensitivity of the contractile proteins (actin and myosin) to Ca²⁺ (Cé, 2008)

11. Mechanoreceptor- A peripheral receptor within the muscle and its vasculature that monitors its physical state and provides rapid feedback to the nervous system (McArdle, 2009, pg. 332).
12. Autogenic inhibition reflex- The relaxation of the antagonist muscle during contractions by a combination of increased neural drive to the stretched muscle(s) and reduced neural drive to the antagonist muscle(s) (Bradenburg, 2006).

13. Stretch shorten cycle (SSC) - The phenomenon that occurs when muscle tissue is stretched to cause eccentric tension immediately before concentric contraction. (Wilson & Flanagan, 2008).


15. VO2max- A leveling off or peaking over in oxygen consumption with increasing exercise intensity which provides assurance that a person has reached maximum aerobic metabolism (McArdle, 2009, pg. 235).


17. Ippon-seoi-nage- Judo specific shoulder throw (Franchini et al., 1998).

18. Uke- Term for judoist (Franchini et al., 1998).

19. Tori- The performer of a test (Franchini et al., 1998).
Delimitations

1. Sample limited to brown/black belt judoists
2. Homogenous population
3. Familiarization of the SJFT
4. Experience of the subjects

Limitations

1. All subjects had the opportunity to get better each time performing the SJFT
2. Outside training or recreation
3. Small sample size
4. Motivation

Assumptions

1. All subjects followed each stretching protocol as assigned
2. All subjects accurately carried out the SJFT and throwing maneuver
3. All subjects gave the same effort each time

Hypotheses

1. Static stretching will have no effect on the judoists index score on the SJFT
2. The judo specific and dynamic warm-ups will produce more throws than static stretching on the SJFT
Chapter 2

REVIEW OF LITERATURE

Stretching is known to improve range of motion (ROM) and physical function, which are important factors in gaining increases in flexibility as well as countering the effects of aging on the body (American College of Sports Medicine [ASCM], 2009). Although the exact mechanisms responsible for increases in ROM are debatable, gains are commonly attributed to decreased muscle-tendon unit stiffness as well as increased tolerance to stretch. Many people stretch before or after exercise with the hopes that increasing ROM will promote better performance and reduce the risk of injury. This is particularly true in activities requiring a large ROM in multiple joints. Beedle et al., (2007) determined that there was no difference in the placement of stretching within a workout in regards to hip, knee, and ankle flexibility; although hip flexibility post-exercise approached significance ($p = 0.06$). The current debate surrounds acute stretching and its effects on athletic performance. Commonly used pre-exercise, static stretching is thought to affect muscle contractile properties; known as the stretch-induced strength loss. This loss is dependent on the stretching technique applied, the contraction type used for measuring loss, and the muscle length at which strength is measured (McHugh & Cosgrove, 2010).

Static stretching is the most common and traditional form of stretching implemented into a warm-up by coaches, trainers, and athletes themselves. Static stretching (SS) involves taking the muscle-tendon unit (MTU) to the end ROM and
holding it there for up to 1 minute before relaxing and then repeating several times (Morse, Degens, Seynnes, Maganaris, & Jones, 2008). The traditional warm-up consists of a submaximal aerobic component (i.e. running, cycling) designed to increase core and body temperature 1-2°C, followed by a period of static stretching for 15-60 seconds to effectively increase ROM, then concluded with a segment of skill rehearsal, where athletes perform similar movements as the sport or event participating in (Behm & Chaouachi, 2011). In agreement with this notion, Murphy, Di Santo, Alkanani, & Behm, (2010) reported an ASA (active-static-active) warm-up of 5 minutes of treadmill running before and after 36 seconds of static stretches produced 41.4% and 75.2% greater hip flexion ROM overall than SS and active stretching, respectively. These benefits in ROM persisted over a 30 minute time span, allowing the positive effects of the aerobic component of the warm-up to increase metabolic and neural responses to the muscle.

Another type of stretching that is replacing static stretching in the modern warm-up and gaining popularity among track & field, football, soccer and rugby athletes is dynamic stretching (DS). Due to its “active” nature, this type of warm-up is designed to increase core and muscle temperature, blood flow, and prepare the body for exercise (Fletcher & Jones, 2004). It has been shown that there is no stretch-induced strength loss with dynamic stretching (Herda et al., 2008). Less research has been conducted on the martial arts population, like Judo, which has not determined whether static stretching benefits or inhibits performance.
The martial art, Judo was founded in 1882 by Professor Jigoro Kano. Judo, “the gentle way” is a descendent of jujitsu, and revolves around the control of force. Judo has grown into one of the most popular sports in the world, and was first introduced into the Olympic Games in Tokyo in 1964. A typical judo warm-up consists of static stretching combined with judo specific techniques to maintain flexibility in the trunk region. Stretching is incorporated into the warm-up with the belief that it decreases the chance of injury as well as increase the range of motion about a joint.

Judo dates back to ancient martial arts and emphasizes the use of proper body mechanics to defeat an opponent with the least effort. It combines throwing and grappling techniques while utilizing pins, chokes, and arm locks (Imamura, Hreljac, Escamilla, & Edwards, 2006). Due to the aggressive throws and falls placed on the athletes, injuries are common; especially with incorrect lifting and throwing mechanics. Current research is lacking in regards to pre-exercise stretching in the judo population. Although many researchers agree stretching prior to athletic activities does not reduce muscular injury, it is less clear whether performance increases, diminishes, or remains unchanged.

It is believed that stretching improves performance and reduces injury, however McHugh & Cosgrave (2010) found that army recruits undergoing high-intensity training suffered overuse injuries; and adding a pre-participation stretching routine did not affect injury risk compared to a formal warm-up. Five out of seven review articles in McHugh’s research found that SS has no effect on injury prevention. Witvrouw, Danneels, Asselman, D’Have, & Cambier (2003) suggest that muscle flexibility is a risk factor for
developing injury in soccer players. Out of 146 athletes, the 67 subjects who suffered injury (with a majority to the hamstrings) were found to have significantly less flexibility than those uninjured. Recommendations include preseason screening as well as prescribed flexibility programs for those with hamstring ROM less than 90° (Witvrouw et al., 2003). The direct relationship between stiffness and injury is not well established. Increased stiffness can lead to increased loading rates, placing a great deal of shock to the lower extremity; possibly predisposing individuals to bone injuries.

On the contrary, those with decreased stiffness may be at risk for excessive joint motion creating soft tissue injury (Butler et al., 2003). Williams, Davis, Scholz, Hamill, & Buchanan (2004) reported that runners with low arches, as well as decreased stiffness, encountered more soft tissue injury than the high arched subjects. For performance, there is some level of stiffness needed to optimize utilization of the stretch-shorten cycle (Butler et al., 2003). A plausible theory to explain why increases in performance may occur with static stretching is that it decreases muscle stiffness, requiring less energy to move the limb allowing greater force production at longer muscle lengths (Shrier, 2004). Alternatively, Butler et al., (2003) examined articles suggesting that lower extremity stiffness increases as the velocity of activity increases, and is necessary to prevent collapse of the lower extremity during the landing phase as well as providing elastic energy return during the propulsive phase. As researchers attempt to address these theories, deficits in performance are being observed with static stretching in a variety of sports in trained and untrained individuals.
**Deficits in Performance**

Acknowledged by Shrier (2004), 20 of the 21 articles reviewed showed that performance variables like force, torque, and jump were all diminished with static stretching. Passive stretching was found not to negatively affect vertical jump performance per se, but to inhibit the positive effect of a warm-up (Cè et al., 2008). Decreases in strength ranged from 4.5% to 28% with various modes of testing including: isometric, isotonic, and isokinetic (Rubini et al., 2007). Most studies focus on lower body exercises, with the exception of Evetovich et al., (2003) and Cè et al., (2008) who investigated the biceps brachii. Force production of the biceps at both slow (30°·s) and fast (270°·s) angular velocities were hindered with static stretching (Evetovich, 2003). Similarly, acute static stretching caused a decrease in peak torque between the first and second MVC series (51±8 N/cm² and 49±8 N/cm²), respectively (Cè, 2008). Equivocal results were found with another upper body study by Torres, Kraemer, Vingren, Volek, Hatfield, Spiering, Ho, Fragała, Thomas, Anderson, Hakkinen, & Maresh (2008), that resulted in no change between control, static, and dynamic stretches on the 30% 1RM bench press. Peak displacement approached significance in the combined stretching group for lateral throw, but additionally no differences between groups occurred for the overhead medicine ball toss (Torres et al., 2008).

The majority of research on static stretching encompasses lower body functional tests; given the amount of work done by the lower body during exercise. Marek, Cramer, Fincher, Massey, Dangelmaier, Purkayastha, Fitz, & Culbertson (2005) found a 2.8%
decrease in peak torque and a 3.2% decrease in mean power as a result of four static stretching techniques. These stretch-induced decreases were reported at slower velocities of 60 and 90°·s (Marek et al., 2005). The five-step jump and single leg hop tests are commonly used to test lower body power; and the medicine ball throw for total body power. Subjects scored better on all three tests in the dynamic group when compared to static and no warm-up groups (McMillian, Moore, Halter, & Taylor, 2006). Fowles et al. (2000) found that static stretching for 30 minutes reduced MVC torque in the plantar flexors, with deficits lasting approximately 1 hour. Muscle strength endurance tests, like 40% and 60% of body weight during knee flexion resulted in significantly less lifts, and an average decline of 24.4% when subjects statically stretched the limbs (Nelson et al., 2005).

Highly trained student athletes were found to have faster 30m sprint times by 1.9% in a control group when compared to static stretching, even when in combination with a dynamic warm-up (Chaouachi et al., 2010). Similarly, trained rugby players produced significantly faster 20m sprint times when incorporating active dynamic stretching into a warm-up, rather than static stretching (Fletcher & Jones, 2004). Nelson, Driscoll, Landin, Young, & Schexnayder, (2005) also found 20m sprint decreases after SS whether or not the stretch included both legs or just one leg. Less of a stretch-induced deficit has been observed in repeated sprint and change of direction tests after static stretching. Wong, Chaouachi, Lau, & Behm, (2011) observed no significant differences between 30s, 60s, and 90s of static stretching followed by 90s of dynamic stretching.
When observing phases of a 30m sprint (acceleration and maximal velocity) in elite women’s soccer players, decreases of all measures were observed in the static stretching group; with the most negative effects occurring during the acceleration phase of sprinting (Sayers, Farley, Fuller, Jubenville, & Caputo, 2008). Collegiate track & field athletes decreased 40m sprint performance by 3% when engaging in 10 minutes of passive stretching (Winchester, Nelson, Landin, Young, & Schexnayder, 2008). Static stretching, even when preceded by dynamic activities can reduce performance of skills that require high power outputs (Winchester et al., 2008; Beckett et al., 2009; Sim et al., 2009; Sayers et al., 2008; Nelson et al., 2005) due to peripheral and central theories.

**Neurological and Mechanical Mechanisms**

Many authors suspect stretch-induced changes occur due to neurologic adaptations. Decreased amplitude of the surface EMG signals during maximal voluntary contractions provide evidence that the stretch-induced strength loss is a neural effect; although the level of nervous system disruption is yet to be determined (Avela et al., 1999; Costa, Ryan, Herda, Walter, Hoge, & Cramer, 2010; Fowles et al., 2000). These low EMG signals provide reason that motor neuron excitability decreases with slow passive stretches (Avela et al., 1999). In addition to the low neuron excitability, spindle fibers, innervated by mechanoreceptor (type III afferent) and nociceptor pain feedback (type IV afferent) may cause reflex activity with mechanical deformation (Wilson and Flanagan, 2008). Although the autogenic inhibition reflex, through the GTO is popular to
blame for stretch-induced deficits, its rapid response to an intense stretch has only momentary inhibitory effects (Fowles et al., 2000).

Another adaptation that may occur alongside the neurological changes is mechanical alterations in the viscoelastic properties of the muscle, which may in turn alter the length-tension relationship (Rubini et al., 2007). A 47% decrease in MTU stiffness was observed following static stretching at the muscular portion of the myotendinous junction (Morse et al., 2008). Some have postulated that SS mainly effects the eccentric contraction of sprinting, reducing elastic return from the stretch-shorten cycle (SSC) (Fletcher and Jones, 2004). Since the series elastic component (SEC) may already be lengthened at the time of static stretching, the MTU may not have the ability to store and reuse as much elastic energy during the SSC. The amount of elastic energy that can be stored in the MTU is a function of stiffness, therefore because stretching decreases stiffness, there is less elastic energy that can be retained and used (Sayers et al., 2008). This decrease in stiffness and increase in muscle compliance may also reduce the sensitivity of the muscle spindles; and possibly the speed of muscle activation which may account for both mechanisms to cause deficits.

A time delay exists from the onset of muscle activation on the onset of force development is termed electromechanical delay (EMD). After observing decreases in rate of force development (13%) and peak twitch force (9%) in the calf muscles after static stretching for 20 minutes, the stretch-induced deficit is thought to have a mechanical origin (Costa et al., 2010). It is thought to have a synergistic effect with neurologic
mechanisms after Costa et al. (2010) noticed increases in EMD by 28.4%. The elongation of the SEC within the muscle tendinous unit may explain why altered muscle lengths affect neural output to evoke twitch responses or synergistic muscle firing patterns.

**Intensity, Frequency, and Duration**

The ideal stretching protocol in regards to intensity, frequency, and duration for decreasing muscle stiffness and ultimately performance, has received little attention. It is generally recommended in preparation for competition that stretch routines last for 10-30 seconds per muscle group, with 2-3 repeats (Sim et al., 2009). Isokinetic peak torque reductions were shown to occur only after 30 and 60 seconds of quadriceps SS by 8.5% and 16.0, respectively (Siatras et al., 2008). Decreases in isometric force, concentric torque, and eccentric torque following 15 and 30 seconds of static stretching were observed; however no differences were noted between the two, indicating that the duration of the stimuli (15 or 30 seconds) did not influence the degree of force loss following static stretching (Brandenburg, 2006). Mean performance deficits were 4.8% and 5.2% for the 15s and 30s respectively, indicating that a longer duration may further hinder performance values.

Longer durations, like 30 minutes of passive stretching decreased strength by 28%, and 9% decrements were still apparent after 1 hour (Fowles et al., 2000). More practical stretching durations for athletic warm-ups, like 2, 4, and 8 minutes did not alter plantar flexion peak torque when compared to a control condition. No changes in EMG amplitude were apparent in this study, suggesting that short durations did not alter the
muscle activation (Ryan, 2008). These results suggest that the duration, in particular, of static stretching should be short enough to dissipate any stretch-induced deficits, but still provide an acute increase in flexibility. Most literature depicts that when total duration of stretching for a muscle group is more than 90 seconds (i.e. 3 stretches of 30s each) there is an indication for performance impairments. Stretches less than 90 seconds creates variability in the evidence for impairments (Behm & Chaouachi, 2011).

Many research designs use 1-4 isokinetic/isometric muscle contractions to convey stretch decrements in torque and mean power (Ogura et al., 2007; Marek et al., 2005; Fowles et al., 2000; Bacurau et al., 2009; Herda et al., 2008). Only 1 muscle group (hamstrings) was stretched when MVC significantly decreased during knee flexion in regularly training soccer players (Ogura et al., 2007). Authors call attention to the fact that athletic performances generally involve multiple muscle activities and should not be studied individually. With respect to intensity, most research requires that subjects passively static stretch to a point of “mild” discomfort. Although no significant differences were found on repeated sprint tests using this intensity; it could explain why any stretch less than maximal intensity may not provide stretch-induced deficits (Wong et al., 2011). It seems logical not to advise the use of prolonged static stretching prior to engaging in high level athletics or competition.

**Competitive Structure of Judo**

Judo is an Olympic sport requiring high physical, technical, and psychological preparation (Little, 1991). The International Judo Federation (IJF) implemented in 2009
that judo competition consists of one 5-minute period, which can also include extra time to score a full point. Combative in nature, judo consists of intermittent, high intensity exercise lasting anywhere from 3 to 10 minutes per match (Amtmann & Cotton, 2005), with 5-7 matches per day (Franchini, Moraes Bertuzzi, Takito, & Kiss, 2009). There is usually 20-30s of activity, with a 5-10s rest intervals during which the judoists attempt to perform a grip on each other (Franchini et al., 2009). The participant executing a technique is referred to as the tori, while the participant receiving a technique is called the uke (Imamura & Johnson, 2003). The objective of each judo match is to obtain a score of ippon (“full point”). This can occur in one of four ways: throwing an opponent onto his or her back, holding the opponent down on his or her back for 25 seconds, strangling an opponent into submission, or joint-locking an opponent into submission (Amtmann & Cotton, 2005).

Judo athletes, on average, train 5-6 days per week; with training time close to 2.5 hours. Practice begins with some sort of warm-up, various drills (kata), mat-work (ne-waza), fighting practice (randori), and finally stretching (Callister R., Callister, R.J., Staron, Fleck, Tesch & Dudley, 1991). There are no current reports of optimal stretching protocols for judo performance. The traditional warm-up is an individualized routine that aids in judo specific skills (Azevedo, Drigo, Carvalho, Oliveira, Nunes, Baldissera & Perez, 2007). It has not been determined whether this warm-up is sufficient for judo performance and/or injury prevention. The most common injuries received are to the shoulder, knee, ankle, head, and elbow (Amtmann & Cotton, 2005). Judo is one of those
sports which demands high flexibility in the shoulder girdle, trunk, hamstring, and groin regions. Consequently, stretching exercises to increase flexibility have been shown to decrease performance (Shrier, 2004; McHugh & Cosgrave, 2010). Static and dynamic stretching should be compared to a judo specific warm-up to determine the most advantageous technique for sports performance.

The judo population, like that of wrestling and boxing, are structured by weight class. No anthropometrical measurements differed between the Brazilian Judo team and judo reserves, although skinfold thickness and percent body fat were low and circumference values were large for both groups (Franchini, Nunes, Moraes & Vecchio, 2007). Franchini et al. (2007) found a significant negative correlation between the SJFT index and body weight. Competitors of lighter categories (60-81 kg) revealed better fitness scores on the SJFT than heavier athletes (over 100 kg) (Sterkowicz & Franchini, 2001). Not only does judo relate to wrestling by way of weight class, but also muscle mass required to perform similar skills. Iwai, Okada, Nakazato, Fugimoto, Yamamoto & Nakajima (2008) revealed that judoists had a greater absolute and relative cross sectional area of the oblique and quadratus lumborum muscles than wrestlers. These muscles are the prime components in trunk flexion and rotation. Differences related to body mass and body composition can influence competition strategies, varying physiological responses (Sbriccoli, Bazzucchi, Mario, Marzattinocci & Felici, 2007).
Physiological Responses

The physiological responses of judo are similar to those of mixed martial arts (Amtmann, J., Amtmann K., & Spath, 2008), wrestling (Nilsson, Csergo, Gullstrand, Tveit, & Refsnes, 2002), and taekwondo (Matsushigue, Hartmann, & Franchini, 2009). Most agree that judo demands high levels from both the anaerobic and aerobic energy systems. The anaerobic energy system provides the short, quick, all-out bursts of maximal power during the match. Franchini, Sterkowicz, Szmatlan-Gabrys, Gabrys, & Garnys, 2011) reported a higher absolute energy system contribution (86.8 ± 23.6 kJ) from the alactic energy system when compared to both aerobic and lactic systems. There is also a transition to the aerobic energy system in the last bouts of high-intensity intermittent exercise to sustain effort and recover during the brief periods of rest (Franchini et al., 2009). Although judo combat demands high levels from both energy systems, the anaerobic energy system is the primary source. Between 0-30s the anaerobic system contributes 80%, whereas the aerobic provides 20% (Amtmann & Cotton, 2005). Other researchers believe that the aerobic system must be adequate enough to keep the athlete performing at maximum effort to withstand the longer durations. A good aerobic capacity tends to improve the anaerobic threshold. This occurs as exercise increases above a certain work rate threshold, and the anaerobic component of metabolism causes lactate to increase significantly (Azevedo, 2007).

Physiological measurements associated with anaerobic metabolism that are taken during judo research include blood lactate and heart rate in beats per minute (bpm).
Blood lactate concentrations during judo combat provide information on the metabolic demand and implications for training intensities. Heart rate monitoring is utilized as a prescription and assessment of training intensities and physical effort (Azevedo et al., 2007). High levels of lactate found within judoists metabolites (Degoutte, Jouanel, & Filaire, 2003; Sterkowicz et al., 1999; Franchini, Takito, & Bertuzzi, 2005b) indicate a good glycolytic energy production system (Santos et al., 2010). Interestingly, Franchini et al. (2007) found that judoists lactate production was diminished following a second match. Although this contradicts many reports regarding blood lactate after a judo match, it implicates a lower anaerobic contribution and a higher aerobic energy system input in the last bouts of high-intensity intermittent exercise. On average, blood lactate during training has reached anywhere from 8.79 to 17.3 mmol (Nilsson et al., 2002; Franchini et al., 2009; Santos et al., 2010). These high concentrations (12.3mmol/l) fall close to resting values (1.8mmol/l) approximately 60 minutes following matches (Degoutte et al., 2003). Good endurance performance has been marked by decreases in lactate measurements because of the improved blood clearance. Increased transportation of lactate by way of the monocarboxilate (MCT 1 and 4) transporters through the sarcolemma membrane helps to defer the fatiguing component (Azevedo et al., 2007).

Heart rate (HR) is used as an indicator of cardiovascular stress. Scores of 175-185bpm show that judoists perform at maximal levels during combat (Degoutte et al., 2003). Working intensity of the heart reached 96.4% of the maximal heart rate during a judo specific test (Sterkowicz et al., 1999). Another physiological response observed in
this population, VO2 max, has reached levels between 50 and 60 ml/kg/min (Franchini et al., 2007). Significant correlations have been found among the following variables: VO2 max and number of throws in the SJFT (r=0.79); percent body fat and estimated VO2max (r= -0.83) and number of throws in the SJFT (r= -0.70) (Franchini et al., 2007). Another significant finding among weight classes was that VO2max relative to body weight was inversely related to weight division (Callister et al., 1991). No significant gender differences have been found between Italian Olympic judokas in variables like: mean VO2max, blood lactate, and maximal heart rate (Sbriccoli et al., 2007), although typical gender differences have been observed in aerobic power and absolute strength (Callister et al., 1991).

**Fitness Testing of Judo Athletes**

Few fitness tests have been developed for judoists that provide both valid and accurate information on competitor’s ability to exert effort. Currently, the Wingate cycle ergometry test provides a reasonable assessment of anaerobic metabolism in judoists (Sbriccoli et al., 2007). Field tests that are gaining popularity within the judo community include the “Santos Test” (Santos et al., 2010), and the Special Judo Fitness Test (SJFT), (Sterkowicz, 1995; Franchini et al., 2011; Franchini, Nakamura, Takito, Kiss, & Sterkowicz, 1998) because of their specific, yet simple administration that mimic competition. As mentioned earlier, research designs using very few muscle contractions on an isokinetic or isometric dynamometer may provide valuable information of stretch-induced impairments in the recreationally active; however sport recommendations should
not be made unless tested using a sport specific test, like the SJFT. Heart rate, VO2max, and lactate concentration show no significant differences between laboratory and field tests, providing reason to carry out more noninvasive tests like SJFT (Sterkowicz et al., 1999).

The SJFT uses two judokas of similar body mass of the performer and are positioned 6 meters of distance from each other, while the performer of the test is in the middle (3 meters) of the judoists to the thrown. The fitness test is then divided into three periods of 15 seconds (A), 30 seconds (B), and 30 seconds (C) with intervals of 10 seconds rest. During each of the three working periods, the performer throws each of their partners using the *ippon-seoi-nage* technique as much as possible. This throw utilizes a forward momentum and requires less collision than other common judo throws (Imamura et al., 2006). Heart rate and number of throws are calculated and compared to a fitness index. It is important to note that a higher index score indicates poor SJFT performance. The SJFT index has been shown to be correlated with both aerobic power (treadmill test) and anaerobic capacity (Wingate test) (Sterkowicz et al., 1999). Fitness testing is valuable to coaches and athletic trainers who look to evaluate judoist’s physical condition with means to maintain or modify training protocols because of its reliability. All groups of judoists (cadets, juniors, and seniors) were alike in regards to number of throws on the SJFT, heart rates, and performance index. Judoists, at least 16 years, introduced to the same type of training as other judo athletes, can attain the same level of performance, irrespective of age (Franchini et al., 1998).
Summary

Little (1991) suggests that successful judo performance is dependent upon the athlete having not only high technical and psychological abilities, but immense power, strength, endurance, and flexibility. Muscle strength performance is dependent upon trunk rotation and lateral flexion for the majority of standing as well as groundwork techniques in judo competition (Iwai et al., 2008). Flexibility is promoted as an important component of physical fitness, especially in athletes whose sports require an extensive range of motion about a joint, like Judo. Although there were no short-term effects of stretching on upper-body performance in track & field athletes (Torres et al., 2008), there is very little research assessing stretching protocols in general for judo athletes.

Callister et al. (1991) describes a judo warm-up consisting of various drills (kata), mat work (ne-waza), fighting practice (randori), and lastly stretching. Shorter durations of stretching within a warm-up, such as a total duration per muscle of <30 s may not negatively impact performance, especially in the highly trained (Behm & Chaouachi, 2011). In activities requiring large ranges of motions in various joints, participants need to perform some form of pre-participation activity to achieve the desired flexibility gains for their activity. Whether this can be achieved by stretching alone, warm-up alone, or in combination, warm-up and stretching has not been established in the literature (McHugh & Cosgrave, 2010).
Chapter 3

METHODS

The purpose of this study was to examine the effects of various stretching protocols on the SJFT of elite judo competitors. An experimental design was utilized. Heart rate data was collected pre-, immediately post, and 1 minute post SJFT. Number of throws was recorded each round, with the total number calculated post SJFT. Statistical comparisons were made between static, dynamic, and judo specific stretching protocols to determine which routine provided the greatest increase in performance.

Subjects

Eight males and 1 female judoist with mean age of 29.62 ± 6.16 years old were recruited for this study. The experimental inclusion criteria required the judoists to be brown or black belts. Each subject served as their own control and was matched with 2 other judoists of similar weight stature for the SJFT. All subjects were familiarized with the SJFT 1 month prior to data collection, and were required to use the test in periodically in training. Nine subjects initially enlisted in this study however one dropped due to injury outside of training or thesis research. See Table 1 for subject characteristics. Subjects were volunteers and classified as low risk according to the American College of Sports Medicine Guidelines (ACSM, 2009). Subjects gave their informed written consent prior to enrollment in this study (Appendix A). All experimental procedures were explained and questions were answered upon their first visit to the Sacramento State Judo training facility.
Table 1

Subject characteristics

<table>
<thead>
<tr>
<th>Subject characteristic</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>29.62 ± 6.16</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>174.62 ± 11.01</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>93.98 ± 20.30</td>
</tr>
<tr>
<td>Body Mass Index (BMI)</td>
<td>31.0</td>
</tr>
</tbody>
</table>

**Procedures**

Subjects reported to the Sacramento State judo training facility on 4 separate occasions over 7 weeks. The first session was separated from the rest by 4 weeks to optimize familiarization and decrease learning effect. The last 3 sessions were separated by 1 week and lasted approximately 1 hour. Attempts were made to control for any confounding variables. For example, (a) testing occurred at 6:30pm each day, with subjects asked to refrain from food ingestion 1 hour prior to testing, (b) subjects were tested in the same room each session as normal practices would be held in, (c) subjects were not to exercise 24 hours prior to test day, (d) subjects were queried for injuries, illness, or excessive fatigue, and (d) subjects were reminded of the importance of giving maximal effort each day before testing.

All subjects attended a familiarization session 1 month prior to actual testing which enabled them to become comfortable with the SJFT. During the 3 test sessions, student researcher led all subjects through the warm-ups together since all 3 groups were
tested all at once. The dynamic stretches (Figure 2), static stretches (Table 3), and the control consisted of a judo specific (JS) warm-up (Table 4). Subjects performed the three stretching protocols on different days to account for any biasing effects, but at the same time each day to mimic normal training sessions. Each warm up session lasted approximately 8 minutes, and subjects began the SJFT within 2 minutes of completing the stretching protocol. Heart rate measurements were taken during the three testing sessions to observe changes in total body stress due to stretch protocols. The number of throws during the SJFT was also recorded to compare fitness levels on a judo specific index.

**Heart Rate**

Subjects HR was obtained by a Polar Heart Rate monitor (T-31; Polar Electro). An abdominal band was worn by the subjects prior to and during the SJFT. The HR watch was placed on the right wrist prior to and during the SJFT for HR readings. These readings were made immediately posttest, and 1 minute following the completion of the test.
**Stretching Protocols**

Subjects executed the stretching and judo specific warm-ups 10 minutes prior to testing and were closely monitored by the student and primary investigators. The magnitude of stretch was maintained subjectively by athletes, as they held the stretches to a point of mild discomfort. The DS protocol was performed across a 7 yard mat with the student investigator leading the warm-up. The SS protocol was also led by the student investigator, with stretches lasting 15 seconds, performed bilaterally. The judo specific warm-up, led by club sensei, included a mixture of static stretches and dynamic movements. All protocols lasted approximately 8 minutes, with 2 minutes to prepare for testing.

Table 2

Dynamic warm up

<table>
<thead>
<tr>
<th>Dynamic stretch</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crossover skips</td>
<td>Skip 7 yards, crossing arms in front and away from your body.</td>
</tr>
<tr>
<td>Knee to chest</td>
<td>Pull one leg up to your chest going up on the ball of the other foot. Switch and repeat for 7 yards.</td>
</tr>
<tr>
<td>Lunge with hip flexor stretch</td>
<td>High foot lunge with arms overhead. Stretch backwards for hip flexor and twist body around front leg.</td>
</tr>
<tr>
<td>Lateral squat</td>
<td>Move sideways for 7 yards in a squat position,</td>
</tr>
<tr>
<td>Exercise</td>
<td>Description</td>
</tr>
<tr>
<td>-----------------------</td>
<td>-----------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Quad stretch</td>
<td>Grab the shin and pull toward the chest while going up on the ball of the other foot. Switch and repeat for 7 yards.</td>
</tr>
<tr>
<td>Lateral jack</td>
<td>Perform jumping jack laterally for 7 yards.</td>
</tr>
<tr>
<td>Groin stretch</td>
<td>Step to the side with one leg stretching the groin. Switch and repeat for 7 yards.</td>
</tr>
<tr>
<td>Straight leg kicks</td>
<td>Using opposite arm/opposite leg, kick leg forward reaching for it with hand.</td>
</tr>
<tr>
<td>Fast carioca</td>
<td>Same as slow carioca but increase speed for 7 yards.</td>
</tr>
<tr>
<td>High knees</td>
<td>Perform a high knees run with short but quick steps across the mat.</td>
</tr>
<tr>
<td>Back pedal</td>
<td>Facing the other direction, take small repeated steps backwards.</td>
</tr>
<tr>
<td>Inch worm</td>
<td>Begin by bending over and walking hands out into a push up position. With little steps, bring legs up toward the hands and repeat.</td>
</tr>
</tbody>
</table>
### Table 3

Static stretching warm up

<table>
<thead>
<tr>
<th>Static stretch</th>
<th>Description (1x15s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sitting hamstring/back stretch</td>
<td>Sitting with legs spread apart in front of you, first bend forward between legs then to each side.</td>
</tr>
<tr>
<td>Quad stretch</td>
<td>In a sitting position grab ankle of one leg and pull foot towards the buttocks. The other leg should be extended out forwards.</td>
</tr>
<tr>
<td>Piriformis stretch</td>
<td>In the supine position, bring one leg over the knee of the other and pull thigh towards your chest.</td>
</tr>
<tr>
<td>Trunk stretch</td>
<td>Standing with feet spread apart, lean over to one side with arm overhead.</td>
</tr>
<tr>
<td>Groin stretch</td>
<td>Standing, lean over to one side, bending one leg and leaving the other straight.</td>
</tr>
<tr>
<td>Calf stretch</td>
<td>Bending at the waist so hands are on the mat, stretch one calf out while the other is resting on the stretched side, switch.</td>
</tr>
<tr>
<td>Prayer stretch</td>
<td>Sitting back on legs, extend arms forward and hold. Perform bilaterally.</td>
</tr>
<tr>
<td>Shoulder stretch</td>
<td>In the crouched position, bring one arm across body</td>
</tr>
</tbody>
</table>
with palm upwards. Perform bilaterally.

<table>
<thead>
<tr>
<th>Overhead arm pull</th>
<th>Bring one arm across the body grabbing upper arm with the free hand.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wrist/fingers</td>
<td>In the seated position stretch and rotate these joints bilaterally.</td>
</tr>
<tr>
<td>Scorpion stretch</td>
<td>Lying on the stomach with arms extended out to the side, bring leg up and behind trunk, switch.</td>
</tr>
</tbody>
</table>

Table 4

Judo specific warm up

<table>
<thead>
<tr>
<th>Judo Specific</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Foot sweeps (50x)</td>
<td>Moving side to side, sweep foot along floor.</td>
</tr>
<tr>
<td>Hamstring/hip flexor</td>
<td>Sitting with legs spread apart, lean to one side, then the other to stretch hamstrings. Lean forward onto one leg to stretch hip flexor, switch.</td>
</tr>
<tr>
<td>stretch (10s each)</td>
<td></td>
</tr>
<tr>
<td>Trunk side stretch (8s)</td>
<td>Standing, lean to one side then the other with arms overhead.</td>
</tr>
<tr>
<td>Trunk rotator stretch (8s)</td>
<td>Standing, rotate body from side to side.</td>
</tr>
<tr>
<td>Hip circles (10s)</td>
<td>On all fours, circle hip inside body and away from body, switch.</td>
</tr>
<tr>
<td>Exercise</td>
<td>Description</td>
</tr>
<tr>
<td>----------------------------------</td>
<td>-----------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Knee bends (8s)</td>
<td>Bouncing from kneeling position to standing position, stretch hamstrings.</td>
</tr>
<tr>
<td>Leg side stretch (10s)</td>
<td>Lean to one side with straight leg on the other, stretching groin. Switch.</td>
</tr>
<tr>
<td>Quad stretch (10s)</td>
<td>Sitting in hurdlers position, lean back to stretch quad. Switch.</td>
</tr>
<tr>
<td>Shoulder stretch (10s)</td>
<td>Sitting, reach one arm across the other and pull. Switch.</td>
</tr>
<tr>
<td>Seal stretch (10s)</td>
<td>Lying on the stomach, push body upwards to stretch abdominals.</td>
</tr>
<tr>
<td>Finger, wrist, and ankle rotations (10s)</td>
<td>Rotate ankles and wrists to stretch flexors and extensors.</td>
</tr>
<tr>
<td>Forwards rolls (3-5 rolls)</td>
<td>Standing, perform a forward roll into side body landing.</td>
</tr>
<tr>
<td>Backwards rolls (3-5 rolls)</td>
<td>Standing, perform a backward roll.</td>
</tr>
<tr>
<td>Forward rolls with legs spread (3-5 rolls)</td>
<td>Same forward roll with spread legs.</td>
</tr>
<tr>
<td>Backwards roll with legs spread (3-5 rolls)</td>
<td>Same backwards roll with spread legs.</td>
</tr>
<tr>
<td>Handstand into forward roll (3-5 rolls)</td>
<td>Perform a handstand, then forward roll out of it.</td>
</tr>
<tr>
<td>Backward roll into</td>
<td>Perform backwards roll with handstand out of it.</td>
</tr>
</tbody>
</table>
handstand (3-5 rolls)  

<table>
<thead>
<tr>
<th>Cartwheels both sides (3-5)</th>
<th>Standing facing the side, cartwheel.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Judo shoulder rolls (3-5)</td>
<td>Forward rolls with judo landing on one side of body with arm slap at the end.</td>
</tr>
</tbody>
</table>

**Special Judo Fitness Test (SJFT)**

Two judoists (*uke*) of similar stature and body mass of the judoist performing the test are stationed 6m of distance from one another, while the performer (*tori*) is 3m of distance from the judoists to be thrown. The test is divided into three periods of 15s (A), 30s (B), and 30s (C) with intervals of 10s. During each of these periods the performer runs back and forth throwing the partners utilizing a basic judo shoulder throw, *ippon-seoi-nage* (Figure 1). Immediately after, and 1 minute following the test HR is verified. The total number of throws during the test as well as HR measurements are added and fit into a fitness index (Table 5).
Figure 1 Image of the ippon-seoi-nage technique (judo.tao.com)
Table 5

SJFT index

<table>
<thead>
<tr>
<th>Classification/Variables</th>
<th>Number of throws</th>
<th>HR after</th>
<th>HR 1 min</th>
<th>Index</th>
</tr>
</thead>
<tbody>
<tr>
<td>Excellent</td>
<td>≥29</td>
<td>≤173</td>
<td>≤143</td>
<td>≤11.73</td>
</tr>
<tr>
<td>Good</td>
<td>27-28</td>
<td>174-184</td>
<td>144-161</td>
<td>11.74-13.03</td>
</tr>
<tr>
<td>Regular</td>
<td>26</td>
<td>185-187</td>
<td>162-165</td>
<td>13.04-13.94</td>
</tr>
<tr>
<td>Poor</td>
<td>25</td>
<td>188-195</td>
<td>166-174</td>
<td>13.95-14.84</td>
</tr>
<tr>
<td>Very poor</td>
<td>≤24</td>
<td>≥196</td>
<td>≥175</td>
<td>≥14.85</td>
</tr>
</tbody>
</table>
Statistical Analysis

The experimental data was expressed as means and standard deviations using STATISTICA (StatSoft, INC), version 6.1. To determine whether any of the three warm-up protocols influenced performance on the SJFT, HR, throws, and index values were analyzed using two-way repeated measures ANOVA. A tukey’s post-hoc analysis was used to determine differences between the three pre-exercise warm-up/stretching conditions. The alpha significance level was set at 0.05.
Chapter 4

RESULTS

The current investigation examined the effects of pre-exercise warm-up on a judo fitness test; including the variables like heart rate and judo throws. Seven healthy males and 1 female judoist (Age = 29.6 ± 6.16 years, Ht = 174.6 ± 11.01 cm; Wt 93.98 ± 20.30 kg) who regularly trained with the judo club 6.5 hours per week and 3 days a week, volunteered as subjects for the study.
Heart Rate

Figure 2 Mean values of heart rate (bpm): resting, post SJFT, 1-minute post fitness test

There were no significant main effect findings between warm-up type, however there was a significant main effect of time on heart rate ($p = 0.0000$). Tukey’s post hoc analysis found that post-HR was significantly higher than pre-HR, and 1 minute post-HR dropped significantly from post-HR. No interaction effects were observed.
Figure 3 Throws per round (1-3) and total (4)

There were no significant main effect findings between warm-up type, however there was a significant main effect of time on throws per round ($p = 0.0000$). Tukey’s post hoc analysis found that the second round and third rounds were significantly higher than the first and that the mean total number of throws was significantly higher than all three rounds. No interaction effects were observed.
SJFT Index

Figure 4 Main effect of warm-up for index scores

There is a significant downward trend ($p<0.059$) in index scores between warm-up trials. The main effect of warm-up type approached statistical significance with the static stretching protocol. The static stretching warm-up decreased SJFT index by one, which increased performance.
The results of the current study suggest that the hypotheses, static stretching will have no effect on judoist’s fitness index, and dynamic & judo specific warm-ups will produce more throws on the SJFT were not supported. Also, variables measured, like HR and throws did not significantly differ between warm-up trials.
Chapter 5

DISCUSSION

The current investigation was the first to evaluate various warm-ups on the SJFT to assess acute effects of stretching on performance. The present index scores exhibited a significant downward trend for static stretching to lower index scores (improve performance). This finding goes against our hypotheses, and further encourages the use of acute static stretching for a short duration before judo activity. This research could have had an order effect that influenced greater performance over each data collection session; however we had hoped to limit those effects with the familiarization period. We also believe that the drop of one subject could have affected the outcome since our sample size was already extremely small. Very little research has provided the judo community with proper warm-up techniques to enhance performance; however our research may have contributed to future stretching recommendations.

Four sessions of warm-ups and SJFT testing were completed over seven weeks and physiological variables from sessions 2-4 were compared. The SJFT is a widely used fitness test in judo research. Demonstrated to be highly reliable, it provides an adequate marker of anaerobic fitness with important aerobic contributions in the short pauses between high-intensity actions (Franchini et al., 2011).

Like the CSUS judo club team warm-up, Franchini (2011) required judo subjects to engage in an active warm-up consisting of running, stretching, throwing techniques, more stretching, and lastly strength exercise. Using this warm-up routine, Franchini
(2011) found that his 14 male black belts had a mean index score of 14.37 ± 1.3, classifying participants as “poor” due to HR measurements taken post and 1 minute following testing. These elite subjects who had trained 7-10 years and all familiar with the SJFT may have done so poorly on the test due to the high involvement of muscle mass performing high intensity movements, various fitness levels, and the structure (work:rest) of the test. When compared to national Brazilian and Polish judo players, high level (more than 10 years training) judo athletes had similar total number of throws and a lower index score compared to non-elite judo players. This high level of anaerobic capacity (as inferred by number of throws) and balance between anaerobic and aerobic (inferred from the index) is indicated for high-level judo performance (Franchini et al., 2007). Not only is energy system contribution an important factor in the SJFT, but body composition as well.

In one study, a negative correlation between body fat percentage and number of throws in the SJFT ($r = -0.70$) in high-level judo players was found (Franchini et al., 2005b). Sterkowicz & Franchini (2001) also found that subjects in lighter categories (60-81kg) revealed better specific fitness, whereas heavier athletes, especially over 100kg, were characterized by lower results with respect to SJFT. One could say that this test favors the lightweight categories. Despite using highly trained judoists (3-10 years), our data under consideration used judoists of larger weight divisions, which could account for the “poor” outcome. On the contrary, the present results indicate that the one subject with an index score of 12.33 (“good”) was in the heavyweight division (>100kg) and had a
high probability of increased body fat. Although better results have been observed in lighter weight categories than heavier ones (Franchini et al., 2005b, Sterkowicz & Franchini, 2001), the phenomenon seen with our research could indicate that our heavyweight subject had good HR recovery and was well trained. The average BMI for our subjects was 31.0; further emphasizing the fact that training status may not have shown in the SJFT overall fitness scores, but rather decreased performance scores due to body composition. Our small sample size was a relatively obese population accounting for the SJFT outcome. As concluded by Callister et al. (1991), judo athletes as well as most combative sports do not represent a homogenous group and must be studied further to determine success predictors across weight divisions. Not only must physiological measurements like HR and blood lactate continue to evolve in judo research, but anthropometric measurements as well.

The age of our subjects, 29.63 ± 6.16 (21-41 years old) had no significant effect on test outcome with various warm-ups. Although research demonstrates that college-aged individuals who static stretch before engaging in activity find decreases in performance, Handrakis (2010) proposes that these findings do not alter the performance of middle-aged adults. As suggested by Handrakis (2010), these active adults respond to stretching differently due to differences in the viscoelastic properties and stiffness of their musculotendinous units. Coincidentally, middle-aged martial arts subjects improved their dynamic balance with static stretching for 10 minutes and had no change in broad jump or single hop (Handrakis, Southard, Abreu, Aliosa, Doyen, Echevarria, Hwang, Samuels,
Venegas, & Douris, 2010). Despite a wide array of ages in the current study, some populations (judo) may still find improvements in flexibility without impairing performance (Behm & Chaouachi 2011).

The duration and intensity of stretch used in the current research consisted of <8 minutes of individual stretches to a point of mild discomfort. Longer durations of 15-60 minutes do not reflect common pre-exercise routines among trained athletes, and cause sprint impairments (Winchester et al., 2008; Beckett et al., 2009; Fletcher & Jones, 2004; Sim et al., 2009; Sayers et al., 2008; Nelson et al., 2005), decreases in MVC (Ogura et al., 2007) and muscle strength endurance from 4.5% to 28% (Nelson et al., 2005; Rubini et al., 2007; Fowles et al., 2000). Ryan et al. (2008) found that practical durations of stretching (2, 4, or 8 minutes) did not alter plantar flexor peak torque, but alternatively caused temporary increase in ROM. Shorter duration stretching within a warm-up, where total duration per muscle group of <30s may not negatively affect performance; especially in the well trained populations (Behm & Chaouachi, 2011).

Those in favor of static stretching of the lower extremity musculature propose that, when placed on stretch, afferent signals increase from golgi tendon organs and muscle spindles to the spinal cord, cerebral cortex, and cerebellum (Handrakis et al., 2010). Those who oppose this notion have strong evidence that static stretching delays electromechanical signal (Costa et al., 2010) and may alter the length-tension relationship of the MTU by causing a plastic deformation of the connective tissues that help transfer force from the contractile components to the bone (Fowles et al., 2000). Neural
mechanisms for stretch impairment have been shown to be fairly transient, whereas mechanical properties, like stiffness, decreases with static stretching; and further decreases with longer stretch durations. Stiffness is strongly correlated to decreased ground contact time which enhances force transmission from the muscular contraction to the skeletal movements (Wilson & Flanagan, 2008).

Because Judo is largely dependent on upper body and trunk strength, studies have shown decreased capability of the biceps brachii at slow and fast velocities during isokinetic contractions (Evetovich et al., 2003). No differences were observed in bench press and medicine ball throw with static stretching, dynamic, or combined routines (Torres et al., 2008). Similar to our research, this non conclusive finding could have been due to the extensive period of rest (5 minutes) after stretching and before the performance. Only 3 judoists could perform the SJFT immediately post warm-up. The SJFT lasted 95 seconds with approximately 2 minutes between subjects switching heart rate monitors. This time interval could have decreased the effect of static stretching. Some would agree that the short duration of static stretches may have had a transient effect on those individuals performing 2nd and 3rd during the test sessions, although it is highly unlikely altogether that static stretching effects persisted for the 1.5 hour test sessions.

It is not very well understood if dynamic stretching increases performance, although most recent data suggests it certainly does not impair it. Followed by static stretching, research indicates that performing dynamic movements helps to remove the
detrimental performance effects induced by static stretching (Chaouachi et al., 2010). Some proposed mechanisms by which dynamic stretching may be the superior choice is due to elevated muscle and body temp, specific skill rehearsal, increases in neuromuscular activity, and postactivation potentiation (Fletcher & Monte-Colombo, 2010). Indicated by the present data, the dynamic warm-up caused the greatest increase in pre-exercise HR, better preparing our subjects for the SJFT. Although this was not a significant finding, it still supports the notion that dynamic warm-ups may better adapt the body for motion.

Of 104 studies in a meta-analytical review, clear evidence exists that (a) pre-exercise SS induces significant negative acute effects on muscle strength and explosive muscle performance, regardless of age, gender, or training status; (b) the acute effects of SS on muscular performance are task-specific, with type of muscle contraction (isometric vs. dynamic) being an important factor; and (c) negative acute effects of acute SS on muscular performance tend to diminish with reduction of stretch duration (Simic, Sarabon, & Markovic, 2012). Many athletes require static flexibility, which helps to acquire skills used in sports like hockey, figure skating, dance, wrestling, and martial arts (Murphy et al., 2010). Judo is an individual sport; however these athletes train as members of a team and participate in the same warm-up protocols unless otherwise directed by the sensei.
Conclusion

The effect of acute static stretching within a sport specific warm-up requires further investigation. In the martial arts population, a typical warm-up routine consists of static stretching, followed by *ukemi* (falling techniques), and lastly *uchikomi* (repetition practice). Although there were no significant findings within the current stretching data, there does exist evidence quantifying increases in performance with static stretching. Prospective research should examine trained vs. untrained judoists as well as a wide range of ages/weight categories. Thus, although static stretching is an effective technique when temporary gains in range of motion are desired, it appears not to be effective in acutely decreasing musculotendinous stiffness for an extended period (Torres et al., 2008). Further static stretching research should be sport specific using intermittent exercise since we found that it increases muscular performance.

The SJFT may provide an approximation of the anaerobic and aerobic demands placed on the body during judo combat, as this test often imposes higher physiological requirements than both training and simulated combat scenarios (Franchini et al., 2011). Future research should investigate the SJFT and heavyweight divisions, since it may favor lightweight judoists on the classification index.
APPENDIX A

Informed Consent

Effectiveness of pre-exercise stretching on a judo fitness test

Thesis purpose

This study is observing the effects of various stretching protocols on a specific judo test to evaluate fitness and physiological parameters of performance. The purpose is to understand stretching on a specific athletic population; Judo athletes. The subjects will be asked to participate in four training sessions and endure a repetitive sprinting test incorporating judo specific throws.

Testing Procedures

Initial _________ 1. Judo specific stress test will be performed during four different testing sessions. With one opponent on either side (~ 20 feet away) you will run to one athlete perform a throw, run to the other and repeat for 15 seconds. Rest 10 seconds, then continue the same procedures for 30 seconds. Rest another 10 seconds, and repeat for 30 seconds. Immediately following, 1 and 5 minutes post testing heart rate will be recorded for physiological values. Heart rate will be measured using a torso strap, meant to be worn during and after the fitness test. This device should not interfere with testing procedures or throwing mechanics.

Risks and Discomforts

This Judo specific fitness test requires a maximum effort from participants and involves a certain amount of risk. During the testing procedure you will experience increased blood pressure, heart rate, increased perceived exertion, muscular discomfort, and fatigue. However, risks of any life threatening events taking place will be minimized by using trained technicians monitoring your physiological responses to the activities and by screening subjects for health problems using a health questionnaire.

Responsibilities of the Participant

Knowledge of your current health status and any abnormalities with it could profoundly affect the outcomes of your test, as well as your safety during the testing procedures. It is your responsibility to disseminate accurate and complete information regarding your health and condition prior to undergoing the test procedures. During the procedure it is your responsibility to provide the technicians with accurate information
regarding how you feel during the test. It is also your responsibility to report any chest pain, tightness, or other abnormal discomforts during the procedures.

Benefits of the Testing Procedure

This test outcome or any part of it may provide you with information regarding your current state of health and physical fitness. The special judo fitness test can be used as a baseline fitness assessment and determine changes in physical state over time as well as various states of conditioning. Results of this testing may be beneficial in developing an exercise program for the enhancement of your current condition.

Freedom of Consent and Inquires

This testing is voluntary and you are free to withdraw from any one of the procedures at any time you feel necessary. Your identity will remain confidential as will the results of testing. Please feel free to ask questions regarding the procedure at any time. This may include clarification on the consent form, instructions on the procedure, or any part of the testing process that you are not comfortable with.

I have read this consent form, and understand the procedure, risks involved and my responsibilities during the testing process. Knowing the risks involved and having had my questions answered to my satisfaction I hereby consent to participate in these tests.

Date ____________________________

Print Name ____________________________

Signature ____________________________

Contact information for researchers:

Primary Researcher
Dr. Daryl Parker
parkerd@csus.edu
Solano 2012
(916) 278-6902

Student Researcher
Kelsey Hammerel
Kinesiology-Exercise Physiology
Graduate student
(925) 759-xxxx
APPENDIX B

Subject Medical History Questionnaire

Sacramento State Health Questionnaire

Name: ____________________________ Date: ____________________________

Age: _______ Sex: M / F  Weight: _______ Blood Pressure _______ / _______

Please answer all portions of questions 1-6.

1. In the past 3 months have you had any of the following injuries/illnesses?

<table>
<thead>
<tr>
<th>ILLNESS</th>
<th>NO</th>
<th>YES</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Irregular heart beat</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chest pain</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Asthma</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Seizures</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>High blood pressure/cholesterol</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fainting spells</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Allergies</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Head injury (mild-severe)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Neck injury</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Shoulder separation</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Back injury</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Knee injury</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
3. Did you participate in sports after your illness/injury? **Yes/No**
   After what time interval? ________________

4. Are you currently taking any medications? **Yes/No**
   Please list medications:
   __________________________________________
   __________________________________________
   __________________________________________

5. If you answered “YES” to any of the illness/injury questions, please explain:
   __________________________________________
   __________________________________________
   __________________________________________

6. I certify that the answers to the above questions are correct and true.
   I also give researchers permission to review this information to determine my exclusion/inclusion from this study. Please sign below.

A Physician **Yes/No**
Name: __________________________

Were you hospitalized for any illness/injury? **Yes/No**
Was surgery performed? **Yes/No**

Date of surgery: __________________________
Kind of surgery: __________________________

Sign: __________________________ Date: ________________
References


