

THE EFFECTS OF SLOW VELOCITY ISOKINETIC
RESISTANCE TRAINING ON HIGH VELOCITY
FORCE OUTPUT FOLLOWING A BRIEF HIGH
VELOCITY FAMILIARIZATION PERIOD

By

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CHAPTER I

INTRODUCTION

Resistance training is often used to improve health, appearance, and athletic performance. There are several variables that can be manipulated when designing a resistance training program. For example, volume (sets x repetitions), frequency (days/week), intensity (amount of weight used), rest intervals between sets, movement pattern, and velocity of movement. The specificity principle implies that gains in torque output occur exclusively in the movements and velocities at which training takes place. Thus, according to the specificity principle, there is little if any benefit for an athlete to resistance train a particular movement and/or velocity that is not encountered in his/her sport.

However, contrary to the specificity principle several physiological adaptations derived from slow velocity/high intensity resistance training seem to indicate otherwise. Such adaptations include preferential hypertrophy of fast twitch (FT) muscle fibers (Hakkinen, Alen, & Komi, 1985; Hakkinen, et al., 2003; Hakkinen, Komi, & Tesch, 1981; MacDougall, Elder, Sale, Moroz, & Sutton, 1977; MacDougall, Sale, & Moroz, 1980; MacDougall, Sale, Moroz, Elder, Sutton, & Howald, 1979; Martel, et al., 2006; Tesch, Thorsson, & Kaiser, 1984; Thorstensson, 1976) , higher concentrations and

activity levels of myosin ATPase (Bell, Petersen, MacLean, Reid, & Quinney, 1992; MacDougall, Ward, Sale, & Sutton, 1977), larger glycogen and phosphocreatine stores (MacDougall, Ward, Sale, & Sutton, 1977), as well as neurological adaptations including: decreased coactivation of antagonists motor units (Amirdis, et al., 1996; Carolan & Cafarelli, 1992), and higher electromyographic (EMG) activity (Aagaard, Simonsen, Andersen, Manussen, & Dyhre-Poulsen, 2002; Aagaard, Simonsen, Andersen, Magnusson, Halkjer-Kristensen, & Dyhre-Poulsen, 2000; Hakkinen, Alen, & Komi, 1985; Hakkinen, et al., 2003; Hakkinen & Komi, 1983; Hakkinen & Komi, 1985; Hakkinen & Komi, 1986; Hakkinen, Komi, & Allen, 1985; Moritani & DeVries, 1979; Nardone, Romano, & Schieppati, 1989; Sale, 1988). These higher EMG activity levels are due to either the recruitment of more motor units, faster firing frequencies of action potentials (rate coding), or greater synchronization. An interesting neurological requirement with acute bouts of resistance training is the need for higher rate coding with increased resistance (Desmedt & Godaux, 1978; Hannerz & Grimby, 1979; Kamen & Knight, 2004; Moritani & Muro, 1987; Van Cutsem, J, & Hainaut, 1998), and/or ballistic contractions (Hannerz & Grimby, 1979; Linnamo, et al., 2000). Whether or not there are further increases in rate coding with long term resistance training is still in question. A final, yet debatable, neurological adaptation is the increase in synchronization of the agonist motor units. Some researchers have found greater agonistic synchronization as a result of resistance training (Milner-Brown, Stein, & Lee, 1975), while others have not seen any change (Kidgell, Sale, & Semmler, 2006; Yao, Fuglevand, & Enoka, 2000).

Despite the contradictory evidence to the specificity of training principle, all of the aforementioned adaptations indicate a potentially improved force capability at higher velocities with typical slow velocity resistance training. For example, FT muscle fibers have a high rate of contraction; therefore, increasing fast twitch muscle cross sectional area (CSA) could possibly assist in greater force production at high velocities. Additionally, myosin ATPase is the enzyme in the myosin filament head that is responsible for the breakdown of adenosine triphosphate (ATP) to adenosine diphosphate (ADP) and inorganic phosphate (Pi) in which energy is released to fuel the movement of the myosin head. Therefore, an increase in concentration and/or activity level of myosin ATPase would potentially allow myosin to pull on the complimentary actin filament causing a shortening of distance between the ends of each sarcomere at a faster rate. Furthermore, the enhanced immediate energy stores in the form of phosphocreatine with accompanied increases in creatine kinase concentrations and activity levels provide immediate fuel sources for muscle contraction. Specifically, the enzyme creatine kinase uses phosphocreatine, ADP, and Pi to rephosphorylate ATP. Finally, with greater synchronization and faster rate coding; evidence points to an enhanced ability to produce torque at high velocities.

The existing research shows contradictory findings in regards to velocity of training. Many researchers have reported that isokinetic resistance training at a specific velocity renders improved force production at predominately that velocity (Aagaard, Simonsen, Trolle, Bangsbo, & Klausen, 1996; Desmedt & Gadaux, 1977; Grimby, Hannerz, & Hedman, 1981; Hakkinen & Komi, 1985; Hakkinen, Komi, & Allen, 1985b ; Iossifidou, Baltzopoulos, & Giakas, 2005; Kanehisa & Miyashita, 1983a; Kanehisa &

Miyashita, 1983b; Kaneko, Fuchimoto, Toji, & Suei, 1983; Moritani & Muro, 1987; Morrissey, Harman, & Johnson, 1995; Newman, Tarpenning, & Marino, 2004; Peterson, Miller, & Wenger, 1984; Pousson, Amiridis, Comette, & Van Hoecke, 1999; Schmidbleicher & Haralambie, 1981). Other researchers have found general adaptations with underlined specific trends; force output increases that are not exclusive to the training velocity but at velocities close to the training velocity as well (Andersen, et al., 2005; Coyle, et al., 1981; Ewing, Wolfe, Rogers, Amundson, & Alan Stull, 1990; McBride, Triplett-McBride, Davie, & Newton, 2002; Moffroid & Whipple, 1970). For example, Coyle, et al. (1981) reported that isokinetic knee extensions performed at $60^{\circ}\cdot\text{sec}^{-1}$ improved torque output at that training velocity as well as at 120 and $180^{\circ}\cdot\text{sec}^{-1}$; however, there were no gains encountered at 240 and $300^{\circ}\cdot\text{sec}^{-1}$. Because there was an improvement in torque output at a velocity that is $120^{\circ}\cdot\text{sec}^{-1}$ faster than the training velocity, this could also be considered a general adaptation as well.

A more general form of adaptations were reported in which torque output was increased at a wide range of velocities as a result of single velocity training (Andersen, et al., 2005; Behm, 1994; Bell, Petersen, MacLean, Reid, & Quinney, 1992; Bell, Snyder, Neary, & Quinney, 1989; Caiozzo, Perrine, & Edgerton, 1981; Colliander & Tesch, 1990; Housh & Housh, 1993; Hunter & Culpepper, 1995; Jones, Hunter, Fleisig, Esamilla, & Limar, 1999; Kanehisa & Miyashita, 1983b; Pipes & Wilmore, 1975; Timm, Sep. 1987; Palmieri, 1987; Wenzel & Perfetto, 1992). A different pattern of general adaptations was seen in which increases in torque output occurred at and below the training velocity (Lesmes, Costill, Edward, Coyle, & Fink, 1978; Moffroid & Whipple, 1970; Narici, Roi, Landoni, Minette, & Cerretelli, 1989). A third pattern sometimes seen

has been general increases in torque with intermediate training velocities e.g. 120 – 180°·sec⁻¹ (Behm D. , 1991; Bell, Petersen, MacLean, Reid, & Quinney, 1992; Housh & Housh, 1993). These increases in torque were seen at, above, and below training velocity.

Finally, other research has supported the notion that the intention to move the resistance as explosively as possible is more important in producing general adaptations in torque output than the actual intensity and velocity at which training occurred (Almasbakk & Hoff, 1996; Behm & Sale, 1993; Cronin, McNair, & Marshall, 2001; Jones, Hunter, Fleisig, Esamilla, & Limar, 1999; Moss, Refsnes, Abidgaard, Nicolaysen, & Jensen, 1997). This type of resistance training places strong emphasis on the time component.

It is possible that neurological adaptations are velocity specific which could lead to a variety of results depending on subjects' past and/or present exposures to physical activity. For example, a person with past experience as a basketball player might undergo general increases in torque output as a result of slow velocity/high intensity resistance training due to the fact that he/she has exposure to high velocity movements such as unweighted sprinting and jumping as can be seen in the sport of basketball. However, an individual without prior experience in high velocity physical activity might demonstrate more specific adaptations as a result of slow velocity/high intensity resistance training. In a seven week training study composed of two, one fast and one slow, training groups, Blazeovich and Jenkins (2002) reported similar training results regardless of group affiliation. Since the subjects in this study were junior elite male sprinters, it appears that concurrent high velocity sports training could nullify differences

in velocity related training adaptations. Furthermore, the adaptations were general with significant increases in hip extension torque at 60 and 271°·sec⁻¹, hip flexion torque at 271°·sec⁻¹, decreased 20 meter sprint time, and increased 1RM squats for both groups.

Purpose of the study

The apparent differences between general muscular and bioenergetic adaptations and specific neurological adaptations via slow resistance training raises an interesting question: given a brief period to become familiar with high velocity movements, would training at slow velocities using maximal or near maximal efforts improve torque production at higher velocities? In essence, is there a way to neurologically “tap into” the muscular and bioenergetic adaptations incurred via slow velocity resistance training for high velocity torque production? With this question in mind, the purpose of the study is to determine the effects of slow/heavy resistance training on high velocity force production following one week of high velocity familiarization training.

Operational definitions:

- *Slow velocities:* $\leq 99^{\circ}\cdot\text{second}^{-1}$.
- *Intermediate velocities:* = 100 - 199°·second⁻¹.
- *Fast velocities:* $\geq 200^{\circ}\cdot\text{second}^{-1}$.
- *Familiarization:* performing 1 set of 10 repetitions at 300 %sec during the last training week (three total training sessions).

Limitations:

- Actual movement velocities in most sporting events are much higher than will be tested in this study (Mann & Sprague, 1980; Ritzdorf, 1998)
- External validity is reduced due to the fact that training and testing will occurred at constant velocities; however, during most physical activities and athletic events velocities vary throughout the movement.
- External validity towards sports and physical activity applications are decreased because most sports and physical activities incorporate multi-joint movements while this study will train and test a single-joint (knee extension) movement.

Delimitations:

- The subjects will only be tested and trained using knee extensions at constant velocities. Isoinertial resistance training and testing will not be used in this study. Isoinertial training allows velocities to vary within the movement.
- There will be no direct measure of the musculature electrical activity during this training study. Therefore, there will be no way to definitively conclude neurological adaptations have occurred.

Assumptions:

- For the experimental and control groups, increases in torque output at velocities not trained at is indicative of muscular and neurological adaptations.
- One week consisting of three days of high velocity familiarization training is enough to induce neurological adaptations (Prevost, Nelson, & Maraj, 1999).

Hypotheses:

- H₁: For the treatment group, maximal torque values will significantly change from Pre to Pre-familiarization test across the three slower velocities (30, 60, and 120°·second⁻¹).
- H₂: For the treatment group, maximal torque values will significantly change from Pre-familiarization to Post-test across the three higher velocities (180, 240, and 300°·second⁻¹).
- H₃: For the control group, maximal torque values will significantly change from Pre-familiarization to Post-test across two velocities (240, and 300°·second⁻¹).
- H₄: Maximal torque output will significantly differ between treatment and control groups at the Pre-familiarization time across the three slower velocities (30, 60, and 120°·second⁻¹).
- H₅: Maximal torque output will significantly differ between treatment and control groups at Post-test across all six velocities (30, 60, 120, 180, 240, and 300°·second⁻¹).

CHAPTER II

REVIEW OF LITERATURE

Fast twitch muscle fiber hypertrophy

There are multiple studies that indicate heavy resistance training results in hypertrophy of FT muscle fibers. For example, Hakkinen, Alen, & Komi (1985) reported that 12 weeks of heavy resistance training resulted in significant ($p < 0.001$) increases in fast twitch muscle fiber areas in young males. In another study by Hakkinen et al. (2003), 21 weeks of resistance training resulted in significant increases in both FT ($p < 0.01$) and ST ($p < 0.05$) fiber areas. MacDougall et al. (1979) also reported significant increases in both fast and slow twitch muscle fiber areas ($p < 0.05$) for young healthy males following six months of heavy resistance training. Additionally, there were greater increases in FT muscles fiber area (33%) compared to slow twitch (ST) (27%). In a subsequent study by MacDougall et al., (1980), seven healthy males showed significant increases in the FT and ST muscle fiber areas of the triceps brachii at 39% and 31% respectively following 5-6 months of resistance training. Similar results were observed following only 8 weeks of resistance training in which the FT/ST fiber area ratio increased significantly (Thorstensson, 1976). Ewing et al. (1990) showed that ten weeks of isokinetic resistance training induced significant increases in both type IIa FT (a more aerobic subtype of type II fast twitch muscle fibers) and ST muscle fiber areas. Tesch

et al. (1984) compared a combined group of weight and power lifters to a group composed of endurance and nonathletes and found that the weight and power lifters had significantly greater FT/ST area ratios compared to both the endurance and nonathletic groups. This would further support the notion that resistance training enhances FT fiber size. This pattern of hypertrophy via resistance training transcends age and gender. For example, FT muscle fiber area of the vastus lateralis was significantly increased ($P < 0.05$) in 22 young males and females (20 – 30 years old) as well as 18 older males and females (65 – 75 years old) as a result of nine weeks of heavy resistance training using knee extension exercises (Martel et al., 2006). Thus, it is clear that traditional slow velocity heavy resistance training induces FT muscle fiber hypertrophy.

Bioenergetic changes

MacDougall et al. (1977) had nine healthy subjects undergo five months of heavy resistance training followed by five weeks of immobilization via an elbow cast. Needle biopsies of the long head of the triceps brachii revealed increases in muscle creatine (39%), creatine phosphate (22%), adenosine triphosphate (18%), and glycogen (66%) stores following training. Furthermore at the conclusion of the immobilization period, creatine phosphate and glycogen content decreased by 25% and 40% respectively. Additionally, significant increases in the activity levels of the enzyme myosinATPase were seen following just five weeks of hydraulic knee extensions at $180^{\circ} \cdot \text{second}^{-1}$ (Bell, Petersen, MacLean, Reid, & Quinney, 1992). Conversely in an older study (Thorstensson, Hulten, von Döbeln, & Karlsson, 1976), eight weeks of resistance training

resulted in an increase in strength; however, there were no changes in ATPase or creatine kinase activity. Furthermore, there were no changes in FT/ST fiber area ratio post-training. Although, disputable evidence pertaining to changes in enzymatic activity exist, the more recent findings have supported positive adaptations in immediate energy production derived from heavy resistance training.

Neurological adaptations

EMG activity

The electrical activity responsible for initiating muscle contraction is measured by electromyography (EMG). Thus, we can assume that higher EMG activity results in greater muscle activation. Factors that can be associated with higher EMG activity such as: greater recruitment and synchronization of motor units as well as higher rate coding (Behm, 1995). Several studies demonstrated overall increases in EMG activity due to resistance training (Aagaard, Simonsen, Andersen, Manusson, & Dyhre-Poulsen, 2002; Aagaard, Simonsen, Andersen, Magnusson, Halkjer-Kristensen, & Dyhre-Poulsen, 2000; Andersen, et al., 2005; Hakkinen, Alen, & Komi, 1985; Hakkinen, et al., 2003; Hakkinen & Komi, 1985; Hakkinen & Komi, 1983; Hakkinen & Komi, 1986; Moritani & DeVries, 1979; Nardone, Romano, & Schieppati, 1989; Narici, Roi, Landoni, Minette, & Cerretelli, 1989). However, none of those studies identified which specific mechanism(s) within the EMG recordings were responsible for the enhanced electrical activities brought about via resistance training.

In a study by Hakkinen et al. (2003) two, all male, training groups were formed. Both groups trained for 21 weeks; however, one group performed combined resistance

and endurance training while the other group resistance trained only. Post-training maximum EMG activity levels of the vastus lateralis were significantly higher than pre-training values for both resistance and resistance plus endurance trained groups with $p < 0.05$ and $p < 0.001$ respectively. Moritani and DeVries (1979) also reported significant increases ($p < 0.002$) in EMG activity in young males and females following eight weeks of resistance training. Furthermore, when two groups trained jump squats; one at 30% of 1RM (SJ30) and the other at 80% (SJ80), McBride et al. (2002) found EMG activity followed a velocity specific pattern of increase. The SJ30 and SJ80 groups had significantly greater increases in EMG activity post-training compared to the control group at their respective training velocities. Further evidence of neural adaptations were seen following 14 weeks of heavy resistance training in which V-wave amplitude ($p < 0.01$) and H-reflex ($p < 0.05$) responses significantly increased. These increases in V-wave and H-reflexes corresponded to $\approx 50\%$ and 20% increases from pre to post-training respectively (Aagaard, Simonsen, Andersen, Manusson, & Dyhre-Poulsen, 2002). V-wave amplitude and H-reflex responses are measures of overall motor activity, α -motorneuron excitability, and presynaptic inhibition. Therefore, as the H-reflex increased there was either an increase in α -motorneuron excitability, a decrease in presynaptic inhibition, or a combination of both. Additionally, the increase in V-wave indicated greater motor activity.

Interestingly, explosive training has also been shown to significantly increase maximal EMG activity (Hakkinen, Komi, & Allen, 1985). Thus, research has led us to believe that humans enhance their ability to generate EMG activity as a result of

resistance training; this underscores the need to investigate which components of the EMG are being improved.

Recruitment of motor units

When dealing with various segments of neurological adaptations via resistance training, there has been considerable disagreement; however, this is not generally the case with motor unit recruitment. The size principle of motor unit recruitment developed by Henneman et al. (1957) is still the popular belief of contemporary thought. The size principle implies that the order of motor unit recruitment follows a graded pattern accompanying incremental increases in force production or movement velocity. Thus the smaller, less force producing, motor units are recruited first, while larger motor units are activated as the demand for force production and/or velocity of movement increases. The question then becomes: can we enhance our ability to recruit additional, high threshold motor units as an adaptation to resistance training? Some researchers believe the answer to this question is “no” because it is believed that at $\approx 85\%$ of maximal voluntary contraction (MVC) most of the motor units are recruited for a given motor pool (De Luca, LeFever, McCue, & Xenakis, 1982; Kukulka & Clamann, 1981; Van Cesteren, Feiereisen, Duchateau, & Hainaut, 1997). Yet other research has shown that strength trained individuals had a greater ability to recruit more motor units than untrained (Fling, Christie, & Kammen, 2008). In the study by Fling et al. (2008), three different indices were used to determine amount of motor unit recruitment. One of the three indices indicated greater recruitment in the strength trained group compared to the untrained group. Although there is disagreement, enhanced ability to recruit more motor units with

resistance training could provide some proof of velocity specific neurological adaptations. Especially in the cases where force output is required at high velocities, then it would seem reasonable to conclude high threshold motor unit recruitment needs to come early in the movement phase.

Rate coding

As stated earlier, one of the neurological components responsible for increasing slow maximal or ballistic torque, is higher rate coding (Desmedt & Godaux, 1978; Hannerz & Grimby, 1979; Kamen & Knight, 2004; Moritani & Muro, 1987; Van Cutsem, J, & Hainaut, 1998). Additionally, the greater force the muscle produces, the greater the rate coding and recruitment of motor units, regardless of training status (Desmedt & Godaux, 1978; Hannerz & Grimby, 1979; Van Cutsem, J, & Hainaut, 1998).

An interesting question posed is: “can resistance training further increase rate coding?” Moritani and Muro, (1987) reported higher rate coding in an elite power lifter compared to normal subjects as intensity was ramped from 0 to 80% of MVC. Furthermore, Linnamo et al. (2000) showed higher mean power frequencies (rate coding) in young males performing explosive exercises compared to slow heavy lifts. Van Cutsem et al. (1998) also documented increases in rate coding following 12 weeks of dynamic resistance training. The most compelling evidence supporting actual enhancements in firing frequencies as a result of resistance training was presented by Kamen and Knight in 2004. In Kamen and Knight’s (2004) study, maximal rate coding of the vastus lateralis increased 15% and 49% in young and old adults respectively following six weeks of resistance training.

Rate coding adaptations through resistance training is not an open and shut case. In a more recent study (Pucci, Griffin, & Cararelli, 2006), there were no changes in mean motor unit firing frequencies after isometric resistance training; however, they only trained for three weeks. In an eight week training study, Rich and Cafarelli (2000) also found no change in average motor unit frequency post-training even though there was a 36% increase ($p < 0.05$) in MVC. A possible reason for this outcome could have been because they only trained isometrically.

More research needs to be done on this topic before conclusive outcomes can be drawn. If future evidence points towards greater rates of action potentials with resistance training, coupled with the fact that there are different rate coding requirements based on how explosive the movement or how heavy the resistance; it is tempting to think that the velocity of resistance training might stimulate specific and/or varying rate coding adaptations. Interestingly, this could be a physiological adaptation that provides evidence for the velocity specific adaptation principle.

Motor unit Synchronization

It would seem logical that the greater number of motor units firing simultaneously would result in greater force production; however, more contemporary research has not supported this notion (Kidgell, Sale, & Semmler, 2006; Yao, Fuglevand, & Enoka, 2000). An older study (Milner-Brown, Stein, & Lee, 1975) using the less accurate surface electrode technique, showed that synchronization of motor units in the same motor pool increased with resistance training. Because there are varying results, more research needs

to be conducted in order to solve this controversy so that greater understanding of mechanisms responsible for maximal force output can be gained.

Specific adaptations

Although most studies have demonstrated somewhat vague patterns of velocity specific gains, few studies demonstrated gains in torque output exclusively at the training velocity. Most research that has supported this finite degree of specificity mixed training and testing modes (isotonic, isometric, and isokinetic). For example, Peterson et al. (1984) isotonic resistance trained 12 elite male swimmers four times/week for five weeks using a hydra-gym yet tested isokinetically on a Cybex II. In this study, all subjects were trained using knee extension at approximately $180^{\circ}\cdot\text{sec}^{-1}$ while being pre and post-tested at 30 and $180^{\circ}\cdot\text{second}^{-1}$. Following the five weeks of training, peak torques increased significantly ($p<0.001$) at $180^{\circ}\cdot\text{sec}^{-1}$ while there were no changes at $30^{\circ}\cdot\text{sec}^{-1}$. Aagaard et al. (1996) also demonstrated highly specific peak torque adaptations following slow velocity/heavy resistance isotonic training while testing isokinetically. Aagaard et al. (1996) trained 22 elite soccer players three times per week for 12 weeks. Prior to the training, the following groups were formed: Heavy resistance (HR) group that trained isotonic knee extensions for four sets of eight repetitions maximums (RM); Low Resistance Group (LR) that only differed from the HR group in that they performed 24RM of isotonic knee extensions; Load Kicking Group (LK) that performed weighted load kicks with a cable; and a Control group. The HR group was the only group that significantly ($p<0.01$) increased concentric peak torque and only at $30^{\circ}\cdot\text{sec}^{-1}$ even though pre and post-testing were conducted at 30, 120, and $240^{\circ}\cdot\text{sec}^{-1}$.

Interestingly, the HR group also significantly increased ($p < 0.05$) eccentric peak torque at 30, 120, and $240^\circ \cdot \text{sec}^{-1}$. Although the training velocity could vary and was not directly assessed; $30^\circ \cdot \text{sec}^{-1}$ was the closest tested velocity to the HR group's training velocity.

Another study that incorporated isotonic training and isokinetic testing also demonstrated velocity, not mode, specific gains in peak torque (Pousson, Amiridis, Comette, & Van Hoecke, 1999). In Pousson's et al. experiment (1999), 12 male subjects trained elbow flexion at 35% of their 1RM using six sets of eight repetitions for seven weeks. Subjects were instructed to perform elbow flexion as fast as possible which tuned-out to range from $302\text{-}312^\circ \cdot \text{sec}^{-1}$. Post-testing resulted in significant increases in peak torque at 240 and $300^\circ \cdot \text{sec}^{-1}$ with no changes at 60, 120, and $180^\circ \cdot \text{sec}^{-1}$. The authors attributed the enhanced peak torque to non-significant and significant decreases in EMG activities of the antagonist triceps brachii at 240 and $300^\circ \cdot \text{second}^{-1}$ respectively.

Kanehisa et al., (1983b) reported specific gains in power output at 73 and $157^\circ \cdot \text{sec}^{-1}$ following six weeks of isokinetic elbow flexion training at those velocities for slow and fast trained groups respectively. Additionally, neither group enhanced power output at the other group's training velocity. Similar to Aagaard's et al., (1996) and Peterson's et al., (1984) studies, Kanehisa et al. (1983a) mixed modes of training (isokinetic) with testing (isotonic). Notice that of these four studies just mentioned, three of them had relatively short training durations of: five weeks (Peterson, Miller, & Wenger, 1984), six weeks (Kanehisa & Miyashita, 1983b), and seven weeks (Pousson, Amiridis, Comette, & Van Hoecke, 1999). It is possible that only neurological, not muscular, adaptations occur under these short duration training periods which would explain the velocity specific adaptation incurred.

Some other research that has supported training velocity specific adaptations involved training and testing using some form of resistance training (isotonic, isometric, and isokinetic) combined with an athletic performance measure e.g. vertical jump, sprint, etc. (Iossifidou, Baltzopoulos, & Giakas, 2005; Newman, Tarpinning, & Marino, 2004; Smith & Melton, 1981). Iossifidou et al. (2005) explored the relationship between peak power of concentric knee extension tested isokinetically and vertical jump. The only significant correlation ($r=.91$; $p<0.05$) was seen between peak power attained during the vertical jump and during the highest tested isokinetic velocity ($300^{\circ}\cdot\text{sec}^{-1}$). Since the velocity of the knee joint during vertical jumping was significantly higher than any isokinetic knee extension test, the conclusion of specificity is supported due to the fact that the higher the velocity tested the stronger the correlation with vertical jumping. Newman et al. (2004) also conducted a correlational study comparing the relationship between various isokinetic knee extension velocities and a measure of athletic performance (sprint times). In the study, the only significant negative correlation occurred between relative isokinetic knee extension peak torque (Newton x Meters/Kilogram) at $240^{\circ}\cdot\text{sec}^{-1}$ and best initial acceleration (10 Meters) sprint performance with $r = -0.714$ ($p<0.01$). Once again we see that as the isokinetic velocity approached the velocity encountered in the athletic event, the stronger the relationship became between the two variables. Additionally, in a study by Smith & Melton (1981), subjects that trained knee extensions at fast isokinetic velocities (180, 240, and $300^{\circ}\cdot\text{sec}^{-1}$) significantly improved vertical jump height ($p<0.05$; 5.38%), broad jump displacement (9.14%), and forty-yard-dash times (decreased 10.11%) while those that trained at slower velocities (30, 60, and $90^{\circ}\cdot\text{sec}^{-1}$) showed smaller increases in vertical

jump height (3.87%), and broad jump displacement (0.42%), while actually increasing (got slower) their forty-yard-dash times (1.12%).

In addition to these studies, several other studies have resulted in velocity specific gains in peak torque output via some form of resistance training (Aagaard, Simonsen, Trolle, Bangsbo, & Klausen, 1996; Grimby, Hannerz, & Hedman, 1981; Hakkinen & Komi, 1985; Hakkinen, Komi, & Allen, 1985b; Iossifidou, Baltzopoulos, & Giakas, 2005; Kanehisa & Miyashita, 1983a; Kanehisa & Miyashita, 1983b; Kaneko, Fuchimoto, Toji, & Suei, 1983; McDouagh, Hayward, & Davies, 1983; Moritani & Muro, 1987; Morrissey, Harman, & Johnson, 1995; Newman, Tarpinning, & Marino, 2004; Peterson, Miller, & Wenger, 1984; Pousson, Amiridis, Comette, & Van Hoecke, 1999; Schmidtbleicher & Haralambie, 1981). Overall there is a lot of research that supports a basic pattern of velocity specific adaptations to resistance training. Unfortunately not many of these studies tested changes in force output isokinetically. To view a comprehensive list of research reporting specific training outcomes using isokinetic testing, see Table 1.

Table 1

Specific adaptations

<i>Author/year</i>	<i>Training Mode</i>	<i>Duration Weeks</i>	<i>Velocity °sec⁻¹</i>	<i>Testing °sec⁻¹</i>	<i>Results: ↑ °sec⁻¹</i>
<i>Aagaard et al. (1996)</i>	Isotonic Knee ext.	12	Not measured Heavy group=8RM Light group=24RM	30, 120, & 240	Heavy 30
<i>Kanehisa et al. (1983)</i>	Isokinetic Knee ext.	8	Slow group 60 Intermediate 180 Fast 300	60, 120, 180, 240, & 300	Slow all velocities; greatest at 60 Intermediate all velocities Fast 240 & 300
<i>Peterson et al. (1984)</i>	Isotonic Knee ext.	5	120 & 180	120 & 180	180
<i>Pousson et al. (1999)</i>	Isotonic Elbow flex.	7	≈302-312	60, 120, 180, 240, & 300	240 & 300

Note. ↑ = Increases; °sec⁻¹ = °second⁻¹

General adaptations with specific trends

The first category of general adaptations that was described earlier, involves a pattern of enhancements in torque production that occur at and close to the training velocity (general with specific trends). Ewing et al. (1990) compared changes in torque output from two different training groups: a slow group that trained at $60^{\circ}\cdot\text{sec}^{-1}$, and a fast group that trained at $240^{\circ}\cdot\text{sec}^{-1}$. Following the ten weeks training period torque increased at 60 and $180^{\circ}\cdot\text{sec}^{-1}$ for the slow group, and at 180 and $240^{\circ}\cdot\text{sec}^{-1}$ for the fast group. Coyle et al., (1981) tested changes in peak torque following slow ($60^{\circ}\cdot\text{sec}^{-1}$), fast ($300^{\circ}\cdot\text{sec}^{-1}$), and mixed (60 and $300^{\circ}\cdot\text{sec}^{-1}$) training velocities while also incorporating a control and placebo group. The placebo group served as a psychological control in which they were administered very light muscle stimulation (Faradic) which was known to produce less than 3% of their maximal voluntary contraction (MVC). Furthermore, subjects from the placebo group were erroneously informed that this stimulation acted as a training stimulus that improved their ability to produce torque. Following the six weeks of training the control group demonstrated no change in torque output at any of the tested velocities (0, 60, 180, and $300^{\circ}\cdot\text{sec}^{-1}$); however, the placebo group showed non-significant improvements of 8% and 3-5% for 0, and 60 - $180^{\circ}\cdot\text{sec}^{-1}$ respectively. The slow group significantly ($p<0.05$) improved torque production at 0, and 60 - $180^{\circ}\cdot\text{sec}^{-1}$ while the fast and mixed groups significantly ($p<0.05$) increased torque at all tested velocities. Interestingly, when comparing the slow, fast, and mixed groups to the placebo group, significant ($p<0.05$) increases followed a training specific pattern in that the slow, fast, and mixed groups improved to a greater extent at 60, 180-300, and 60- $300^{\circ}\cdot\text{sec}^{-1}$ respectively. Furthermore, although the mixed group enhanced torque at all

velocities post-training, the greatest improvements were seen at the training velocities of 60 and 300°·sec⁻¹. In agreement, Moffroid & Whipple (1970) reported subjects training at 36°·sec⁻¹ significantly (p<0.05) increased torque production at 18 and 36°·sec⁻¹ furthermore, the subjects training at 108°·sec⁻¹ significantly increased torque output at 18, 36, 54, 72, 90, 108°·sec⁻¹. Finally, Narici et al. (1989) reported significant (p<0.05) increases in torque at 0, 60, and 120°·sec⁻¹ following 60 days of isokinetic knee extension training at 120°·sec⁻¹. Curiously, there were no changes in torque output at velocities higher than 120°·sec⁻¹. Clearly here is evidence that points to a pattern of specificity; however, increases were not just exclusive to the training velocity. To view a comprehensive list of research reporting general (with specific trends) training outcomes see Table 2.

Table 2

General adaptations with Specific Trends

<i>Author/year</i>	<i>Training Mode</i>	<i>Duration Weeks</i>	<i>Velocity °sec⁻¹</i>	<i>Testing °sec⁻¹</i>	<i>Results: ↑ °sec⁻¹</i>
<i>Coyle et al. (1981)</i>	Isokinetic Knee ext.	6	Slow group 60 Fast group 300 Mixed group 60 & 300	0, 60, 180, & 300	Slow 0, 60, & 180 Fast 0, 60, 180, & 300 Mixed 0, 60, 180, & 300 Mixed greatest 60 & 300
<i>Ewing et al. (1990)</i>	Isokinetic Knee ext.	10	Slow 60 Fast 240	60, 180 & 240	Slow 60 & 180 Fast 60 & 240
<i>Moffroid et al. (1970)</i>	Isokinetic Knee ext.	6	Slow group 36 Fast group 108	0, 18, 36, 54, 72, 90, & 108	Slow group @ & below training velocity Fast group @ & below training velocity
<i>Narici et al. (1989)</i>	Isokinetic Knee ext.	8	120	0, 60, 120, 180, 240, & 300	@ 120 & below No change @ 240 & 300

Note. ↑ = Increases; °sec⁻¹ = °second⁻¹

General adaptations

Now that we are convinced some form of velocity specific adaptations occur via resistance training, a look at other research may muddy the water a bit. To start, it needs to be noted that, according to research, there are a multiple patterns of general adaptations derived from velocity controlled resistance training.

The first category (not truly a distinct pattern) of general adaptations seen in research is a mix of overall general adaptations for both fast and slow training (Caiozzo, Perrine, & Edgerton, 1981; Hunter & Culpepper, 1995; Palmieri, 1987; Pipes & Wilmore, 1975; Smith & Melton, 1981; Wenzel & Perfetto, 1992), and slow training exclusively (Aagaard, Simonsen, Trolle, Bangsbo, & Klausen, 1994; Andersen, et al., 2005; Colliander & Tesch, 1990; Smith & Melton, 1981)

In an experiment that combined isotonic training at 30 and 90°·sec⁻¹ with isokinetic testing at 30 and 240°·sec⁻¹, Anderson et al. (2005) reported 18% (p<0.01) and 10% (p<0.05) increases in torque production at 30 and 240°·sec⁻¹ respectively. Of further interest, iEMG activity significantly (p<0.05) increased at 30°·sec⁻¹ solely. Thus there appeared to be general improvements in torque output; however, specific neurological improvements. The greater neurological improvements might have accounted for the greater increases in torque seen at 30 compared to 240°·sec⁻¹.

In a study by Pipes and Wilmore (1975), a slow training group (24°·sec⁻¹) significantly (p<0.05) increased maximal isokinetic torque production at 24 and 136°·sec⁻¹ on multiple exercises following eight weeks of training. Additionally, the fast training group (136°·sec⁻¹) also showed significant isokinetic torque improvements at 24 and 136°·sec⁻¹ post-training. Colliander & Tesch (1990) also provided evidence for

general adaptations via slow velocity training. In their study, males and females trained for 12 weeks using four-five sets of six maximal repetitions of knee extension exercises at $60^{\circ}\cdot\text{sec}^{-1}$ which led to significant increases in peak torque ($p<0.05$) at 30, 90, and $150^{\circ}\cdot\text{sec}^{-1}$. This compilation of research outcomes suggest general adaptations from both high and low velocity resistance training.

Smith & Melton, (1981) provided another good example of both fast and slow velocity training inducing improved torque outputs at multiple testing velocities. In the study, the slow resistance trained group ($30, 60, \text{ and } 90^{\circ}\cdot\text{sec}^{-1}$) increased ($p<0.05$) knee extension torque by 3.14, 21.32 and 24.73% at 0, 30, and $240^{\circ}\cdot\text{sec}^{-1}$ respectively. Furthermore, the fast trained group ($180, 240, \text{ and } 300^{\circ}\cdot\text{sec}^{-1}$) also significantly ($p<0.05$) improved maximal torque production by 2.25, 3.38, and a huge 60.92% at 0, 30, and $240^{\circ}\cdot\text{second}^{-1}$ respectively. With this study it appears that there were greater adaptations with slow velocity training. Upon further investigation, although general adaptations did occur, there was a pattern of specific adaptations with greater improvements at the training groups' respective training velocities. Finally, the fact that both training groups trained at three different velocities might explain the consequent general adaptations seen.

In further support of general adaptations via fast and slow training, Caiozzo et al. (1981) found that young males and females training at a single slow velocity of $96^{\circ}\cdot\text{sec}^{-1}$ significantly enhanced torque at 0, 48, 96, 144, 192, and $240^{\circ}\cdot\text{sec}^{-1}$ while their counterparts that trained at $240^{\circ}\cdot\text{sec}^{-1}$ significantly increased torque at 144, 192, and $240^{\circ}\cdot\text{sec}^{-1}$. Interestingly, Aagaard et al. (1994) as well as Pipes & Wilmore, (1975) reported slow velocity training alone produced general adaptations in torque. However,

in the study by Aagaard et al. (1994) the fast group might have actually trained with too light a resistance at 24RM to induce increases in torque capabilities at slower velocities.

A second pattern of general adaptations is the reported increase in torque at and below training velocities (Lesmes, Costill, Edward, Coyle, & Fink, 1978; Narici, Roi, Landoni, Minette, & Cerretelli, 1989). In a study by Lesmes, et al. (1978) subjects trained knee flexion and extension at $180^{\circ}\cdot\text{sec}^{-1}$ for seven weeks. Increases in torque production occurred at and below the training velocity (0, 60, 120, $180^{\circ}\cdot\text{sec}^{-1}$) conversely, no changes occurred at 240 and $300^{\circ}\cdot\text{sec}^{-1}$. Furthermore, Narici et al. (1989) reported significant strength changes at 0, 60, and $120^{\circ}\cdot\text{sec}^{-1}$ following four weeks of resistance training at $120^{\circ}\cdot\text{sec}^{-1}$.

A third pattern of general adaptations that are occasionally observed occur when incorporating intermediate velocity training protocols (Adeyanju, Crews, & Meadors, 1983; Behm D. , 1991; Bell, Petersen, MacLean, Reid, & Quinney, 1992; Bell, Snyder, Neary, & Quinney, 1989; Colliander & Tesch, 1990; Housh & Housh, 1993; Kanehisa & Miyashita, 1983b; Timm, 1987). For example, increases in peak torque at 90, 120, 180, 210, and $300^{\circ}\cdot\text{sec}^{-1}$ were seen following just five weeks of hydraulic knee extensions at $180^{\circ}\cdot\text{sec}^{-1}$ (Bell, Petersen, MacLean, Reid, & Quinney, 1992). When training and testing on Cybex II dynamometer, unilateral knee extension peak torque increased at 60, 120, 180, and $240^{\circ}\cdot\text{sec}^{-1}$ ($p<0.05$) following eight weeks of unilateral knee extension training at $180^{\circ}\cdot\text{sec}^{-1}$ (Housh & Housh, 1993). Using a very similar protocol in which subjects trained knee flexion and extension for eight weeks at $180^{\circ}\cdot\text{sec}^{-1}$, Timm, (1987) also found improvements in torque up to $\pm 120^{\circ}\cdot\text{sec}^{-1}$. Finally, although Kanehisa & Miyashita (1983b) found velocity specific adaptations for groups

training at slow ($60^{\circ}\cdot\text{sec}^{-1}$) and fast ($300^{\circ}\cdot\text{sec}^{-1}$) velocities, the group trained at the intermediate velocity ($180^{\circ}\cdot\text{sec}^{-1}$) showed significant ($p<0.05$) increases in maximal torque at 60, 180, and $300^{\circ}\cdot\text{sec}^{-1}$.

A fourth pattern proposed by Behm and Sale (1993) is the intention to move the resistance as fast as possible as the key factor involved in eliciting general adaptations and not the actual velocity of limb movement. Behm and Sale, (1993) trained eight males and eight females for dorsi flexion. One limb performed isokinetic contractions at $300^{\circ}\cdot\text{sec}^{-1}$ with the contralateral limb performing isometric contractions. A key component to this experiment is that subjects were encouraged to move both limbs explosively. Amazingly, both limbs increased maximal torque ($p<0.05$) at 0, 15, 30, 59.6, 89, 173, 240, and $300^{\circ}\cdot\text{sec}^{-1}$ following training. Of further interest, the greatest increases for both limbs were seen at $300^{\circ}\cdot\text{sec}^{-1}$. Two concerns of the study are the fact that they trained a small set of muscles in the dorsi flexors which might hurt external validity applied to other joints and muscle groups, and whether or not the results are due to a cross-over effect from the limb that actually trained at $300^{\circ}\cdot\text{sec}^{-1}$. However, a study by Jones et al. (1999) also supports Behm & Sales' theory that it is the intention to move a resistance as explosively as possible that dictates the training outcome.

Almasbakk & Hoff (1996) reported equal increases in maximal velocity (Torque production was not measured) of movement during bench press exercises for both the heavy resistance trained (80-85% of 1RM) and light resistance trained (wooden stick = 0.37kg) groups. During this six week training study, both groups were instructed to move the resistance as fast as possible. Finally, Moss et al. (1997) also reported equal increases in maximal angular velocity of elbow flexion movements for a heavy (90% of

1RM; G90), intermediate/power (35% of 1RM; G35), and light (15% of 1RM; G15) trained groups when tested at 15%, 35%, and 50% of their pre-training 1RM.

Surprisingly, G90 and G35 showed significantly ($p < 0.05$) greater improvements in maximal angular velocities at 25%, 75%, and 90% of 1RM.

On the whole, there are multiple studies that support general increases in torque production following resistance training protocols that are velocity controlled (Aagaard, Simonsen, Trolle, Bangsbo, & Klausen, 1994; Adyanju, Crews, & Meadors, 1983; Behm D., 1991; Bell, Petersen, MacLean, Reid, & Quinney, 1992; Bell, Snyder, Neary, & Quinney, 1989; Caiozzo, Perrine, & Edgerton, 1981; Colliander & Tesch, 1990; Housh & Housh, 1993; Hunter & Culpepper, 1995; Jones, Hunter, Fleisig, Esamilla, & Limar, 1999; Palmieri, 1987; Pipes & Wilmore, 1975; Sale, 1988; Smith & Melton, 1981; Timm, Sep. 1987; Wenzel & Perfetto, 1992). To view a comprehensive list of research reporting general training outcomes, see Table 3. This final study will be used to further illustrate the complexity between velocity specific and general adaptations derived through resistance training. In the previously mentioned study by Smith and Melton (1981), knee extension training at fast velocities of 180, 240, and $300^{\circ} \cdot \text{sec}^{-1}$ resulted in enhanced torque production at 30 as well as $240^{\circ} \cdot \text{sec}^{-1}$ ($p < 0.05$). Similarly, the slow group increased in torque output at 30 and $240^{\circ} \cdot \text{sec}^{-1}$ ($p < 0.05$) following training at 30, 60, and $90^{\circ} \cdot \text{sec}^{-1}$. Conversely, a highly specific pattern of adaptations were seen when performing vertical jumps, broadjumps and 40 yard dash sprints. Thus in this one study alone controversial evidence has been generated for both general and specific adaptations to varying velocities of resistance training.

Table 3

General adaptations

<i>Author/year</i>	<i>Training Mode</i>	<i>Duration Weeks</i>	<i>Velocity °sec⁻¹</i>	<i>Testing °sec⁻¹</i>	<i>Results: ↑ °sec⁻¹</i>
<i>Aagaard et al. (1994)</i>	Isotonic Hydraulics Knee ext.	12	Heavy group 20 – 50 Light group 100 - 200	0, 30, 120, 180, 240, 300, 360, 480, 600, & 720	Heavy 0, 30, 240, & 300
<i>Anderson et al. (2005)</i>	Isotonic Knee ext.	12	30 & 90	30 & 240	60 & 240
<i>Behm (1991)</i>	Isotonic Shoulder press	10	180	60, 120, 180, 240, & 300	60, 120, 180, 240, & 300
<i>Behm et al. (1993)</i>	Isokinetic Dorsi flex.	16	300	0, 15, 30, 60, 89, 173, 240, & 300	0, 15, 30, 60, 89, 173, 240, & 300
<i>Bell et al. (1992)</i>	Isokinetic Hydraulics Knee ext.	5	180	90, 120, 180, 210, & 240	90, 120, 180, 210, & 240
<i>Bell et al. (1989)</i>	Hydraulics Knee ext.	8	Slow group ≈60 Fast group ≈180	60, 120, 180, & 240	Both groups 60, 120, 180, & 240
<i>Blazevich et al. (2002)</i>	Isotonic Hip flex. & ext.	7	Not measured Heavy group 70-90% 1RM Light group 30-50% 1RM	60, 272, 482	Both groups: hip flex @ 272 hip ext. @ 60 & 272
<i>Caiozzo et al. (1981)</i>	Isokinetic Knee ext.	4	Slow group 96 Fast group 240	0, 48, 96, 144, 192, 240, & 288	Slow 0, 48, 96, 144, 192, & 240 Fast 144, 192, & 240
<i>Colliander et al. (1990)</i>	Isokinetic Knee ext.	12	60	30, 90, & 150	30, 90, & 150
<i>Housh et al. (1993)</i>	Isokinetic Knee ext.	8	120	60, 120, 180, & 240	60, 120, 180, & 240
<i>Lesmes et al. (1978)</i>	Isokinetic Knee flex. & ext.	7	180	0, 60, 120 180, 240, & 300	@ 180 & below
<i>Narici et al. (1989)</i>	Isokinetic Knee ext.	8	120	0, 60, 120, 180, 240, & 300	@ 120 & below
<i>Pipes et al. (1975)</i>	Isokinetic Multiple joints	8	Slow group 24 Fast group 136	24 & 136	Both 24 & 136
<i>Smith et al. (1981)</i>	Isokinetic Knee ext.	6	Slow group 30, 60, & 90 Fast group 180, 240, & 300	0, 60, & 240	Slow 60 & 240 Fast 240
<i>Timm (1987)</i>	Isokinetic Knee flex. & ext.	8	180	60, 120, 180, 240, & 300	60, 120, 180, 240, & 300

Note. ↑ = Increases; °sec⁻¹ = °second⁻¹

CHAPTER III

METHODOLOGY

Participants

Subjects consisted of healthy college-age males and females with a mean age of 22.9 \pm 2.885 years old. There were a total of 23 subjects that started the study. One subject dropped out of the study due to military obligations. Of the 22 subjects that completed the study, nine were males and thirteen females. Subjects were recruited from Kinesiology and Health Studies (KHS) departmental courses at the University of Central Oklahoma (UCO). Specific KHS courses students were recruited from were: Applied Anatomy, and Mechanical Principles/Analysis of Movement. Students were given an incentive of 15 extra credit points in any one of the aforementioned courses for participating in the study. In the unlikely instance in which a student was enrolled in more than one class recruited for this study, the said student received extra credit points in only one of the courses.

Students were randomly selected to a training (treatment) or control group. The treatment group (n = 11) was required to participate in all three testing and familiarization days as well as 80% of the normal training days to receive the 15 extra credit points. The control group (n = 11) had to attend all three testing days as well as all three familiarization training days in order to receive the 15 extra credit points. No partial

extra credit, e.g. 10 points, was given. An alternative writing assignment was given as an optional extra credit assignment for those unable or unwilling to participate in this training study.

All training and testing was performed on a Biodex (Shirley, NY) at the McBride Clinic Inc. (Edmond, OK). In accordance with the Institutional Review Board at Oklahoma State University and The University of Central Oklahoma, all subjects signed an informed consent form prior to participation. Included in the informed consent was a release of liability waiver releasing McBride Clinic Inc. of any liability due to subject injury incurred while training or testing at their facility. Every subject and the principal investigator (Paul House) signed the informed consent/waiver of release.

Biodex setup

Before all training and testing sessions, the Biodex (Shirley, New York) was adjusted to fit each individual properly. The powerhead was set at 0 rotation and tilt. To prevent bias unidirectional torque readings, balancing was set prior to each subject's training and testing sessions. Balancing was performed before subjects were positioned on the Biodex. The red dot on the shaft of the dynamometer was lined-up with the 0° angle on the powerhead scale. The dot on the knee flexion/extension fixture was then attached with the dot on the fixture aligned with the red dot on the dynamometer shaft. To maximize ROM especially during high velocity settings, cushioning was set at hard. In compliance with the Biodex Multi-Joint Systems Manual, sensitivity for the knee flexion/extension fixture was set at C. This was done to reduce the oscillating effects of flexing of the knee apparatus while accelerating to the training velocity prior to reaching equilibrium. Each subject started every training and testing session with the back rest set

at a 90° angle to the sitting pad. Leg extension range of motion (ROM) was set for each individual at 90° flexion (starting position) to approximately 0° flexion (ending position). Positions calibrations and verifications were conducted before all testing sessions for both the control and treatment groups. Finally, according to the Biodex Multi-Joint Systems Manual, torque calibrations were conducted when warnings appeared on the monitor screen.

Training protocol

Prior to any training and testing session, all subjects performed 2 sets of 10 repetitions using approximately 50% of their maximal effort at 30°·sec⁻¹ or, if testing, at the first velocity being tested at. Every subject (treatment or control) was fastened down at the distal thigh, waist, and shoulders by way of the Velcro straps. The lateral femoral condyle was palpated and lined-up with the center of the dynamometer (Biodex Multi-System Manual, 1988). The calf pad was placed on the anterior lower leg proximal to the lateral malleolus and distal to the prominent portion of the gastrocnemius. Individual settings of the knee fixture were documented for each subject and placed at that setting for all subsequent training and testing sessions. During each training and testing session, subjects were instructed to cross their arms with hands placed on opposing shoulders.

The treatment group performed leg extensions ranging from 90° flexion to approximately 0° flexion (depending of variations in subjects' range of motion) with their non-dominant leg. The workouts consisted of 3 sets of 10 repetitions 3 days/week for 7 weeks at 30°·sec⁻¹. The training days were on Mondays, Wednesdays, and Fridays.

During the final training week the treatment group performed the normal protocol with the addition of 1 set of 10 maximal repetitions at 300°·sec⁻¹. There was a 1 minute

and 30 seconds rest period between each set. Of the researchers that reported rest intervals between training and testing sets, most involved 1-2 minute time periods (Behm & Sale, 1993; Bell, Snyder, Neary, & Quinney, 1989; Colliander & Tesch, 1990; Housh & Housh, 1993; Hunter & Culpepper, 1995; Kanehisa & Miyashita, Specificity of velocity in strength training, 1983b; Narici, Roi, Landoni, Minette, & Cerretelli, 1989; Prevost, Nelson, & Maraj, 1999).

Current resistance trained subjects assigned to the control group were instructed to maintain their resistance train program utilizing the same resistance, volume (Sets x Repetitions), frequency. This is to ensure no strength gains or losses were due to changes in personal training protocols. Additionally, the control group did not perform the isokinetic leg extensions during the first six of the seven week training study. On Monday, Wednesday, and Friday of the final training week the control group did perform 1 set of 10 maximal repetitions at $300^{\circ}\cdot\text{sec}^{-1}$. Prevost, et al. (1999) found that only two sessions of high velocity isokinetic leg extensions resulted in significant increases in torque output. It is assumed that this gain in torque was the result of neurological adaptations.

Testing

As recommended in the Biodex User Manual, prior to any testing all subjects were given a day to practice knee extension on the Biodex. Therefore, the Friday prior to week one, all subjects came in and become familiar with the equipment by practicing one set of 10 repetitions at 30, 60, 120, 180, 240, and $300^{\circ}\cdot\text{sec}^{-1}$. The pre-testing and first training day began on the Monday of week one. All subjects were tested for leg extension peak

torque at 30, 60, 120, 180, 240, and 300°·sec⁻¹ during Pre-training (week 1), the week prior to the protocol completion (End of week 6), and Post-training (Monday following week 7). The Pre-familiarization (PFT) testing was conducted just prior to performing the last training day of week six. All tests were performed using the non-dominant leg. For every testing session, all subjects were given three non-consecutive maximal attempts at each velocity. A one and half minute rest period was given between each velocity (Behm & Sale, 1993; Bell, Snyder, Neary, & Quinney, 1989; Colliander & Tesch, 1990; Housh & Housh, 1993; Hunter & Culpepper, 1995; Kanehisa & Miyashita, 1983b; Narici, Roi, Landoni, Minette, & Cerretelli, 1989; Prevost, Nelson, & Maraj, 1999). The highest torque value of the three attempts was recorded as his/her peak torque. The testing order was randomized for all subjects over all six testing velocities. To randomize, six numbers were written on small pieces of paper to represent the six different velocities tested. For example, 1 = 30°·sec⁻¹, 2 = 60°·sec⁻¹ ... 6 = 300°·sec⁻¹. The numbers were turned face down, mixed-up, and drawn in the order to be performed. This was done for each subject from both groups. No subjects shared the same order. Once a pre-test order was determined for a subject, that subject performed the same testing order for all three testing sessions. Verbal encouragement was given to all subjects over all testing periods and velocities. See Figure 1 for a graphic depiction of the timeline for the study.

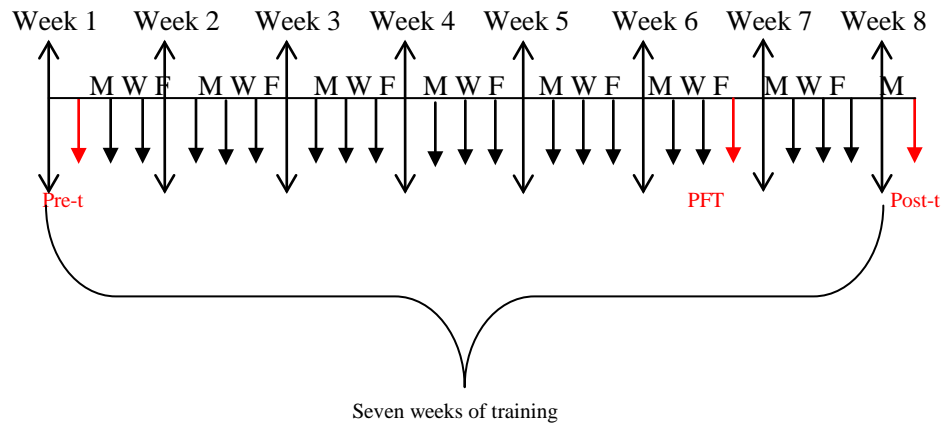


Figure 1 – Testing and Training Schedule

Note. Pre-t = Pre-testing; PFT = Pre-familiarization testing; Post-t = Post-training testing

Statistical Analysis

A Doubly Multivariate Analysis of Repeated Measures (Group x Time) with multiple dependent variables was used to determine if there were overall significance in the weighted combination of the six dependent variables. If significant, then Group x Time, or Group, or Time for each dependent variable was assessed. The six dependent variables were the torque outputs at the six velocities over the three testing periods. For significant main effects and/or interactions, Singly Multivariate Analysis of Repeated Measures was used to determine which dependent variables contributed to the multivariate effect(s). For these dependent variables, post hoc contrasts were run to determine which time period(s) demonstrated the significant change. Independent of the MANOVA, two different repeated measures ANOVA's were run to determine if there were significant changes, for the treatment group only, in torque output at 30, 60, and 120°·sec⁻¹ from Pre to PFT (Hypothesis 1), and at 180, 240, and 300°·sec⁻¹ from PFT to Post-testing (Hypothesis 2). Bonferroni adjustment was used to avoid inflating the alpha by dividing alpha by three or 0.05/3 for hypothesis 1 and 2. A repeated measures

ANOVA was also run to determine if there were significant changes, for the control group only, in torque output at $240^{\circ}\cdot\text{sec}^{-1}$ and $300^{\circ}\cdot\text{sec}^{-1}$ from PFT to Post-testing (Hypothesis 3). Again, Bonferroni adjustment was used to prevent experimentwise error by dividing alpha by two or $0.05/2$. The unadjusted alpha criterion was set at .05. Finally, the Doubly Multivariate Analysis of Repeated Measures with multiple dependent variables was used to determine if there were group differences during the PFT at $30^{\circ}\cdot\text{sec}^{-1}$, $60^{\circ}\cdot\text{sec}^{-1}$, and $120^{\circ}\cdot\text{sec}^{-1}$ (Hypothesis 4), and during the Post-test at all six velocities (Hypothesis 5) . SAS was the program used to record and analyze the data from the study.

CHAPTER IV

FINDINGS

Means and standard deviations for both groups over the three time periods and six velocities are displayed in Table 4 and Figure 2. The results of the 2 x 3 (Group x Time) MANOVA showed a significant omnibus effect with a Wilks' Lambda = 0.093, $F(6, 15) = 24.37$, $p < 0.0001$. Further MANOVA analysis showed no interaction of group x time and no main effect for group with $p = 0.1724$, and $p = 0.6393$ respectively. However, there was a significant main effect for time with velocity as the dependent variables, Wilks' Lambda = 0.175, $F(12,9) = 3.53$, $p = 0.0333$.

Table 4

Torque Means and Standard Deviations

Velocity	Group	Pre		PFT		Post	
		Mean	SD	Mean	SD	Mean	SD
30°·sec ⁻¹	Control	135.5	38.0	138.8	39.4	146.9	47.2
30°·sec ⁻¹	Treatment	122.4	56.5	134.3	52.6	140.9	56.3
60°·sec ⁻¹	Control	122.4	34.5	126.5	31.0	129.1	28.6
60°·sec ⁻¹	Treatment	110.8	58.1	124.7	52.0	132.4	50.5
120°·sec ⁻¹	Control	93.2	22.6	110.6	28.4	109.7	27.7
120°·sec ⁻¹	Treatment	89.3	46.3	93.2	40.5	102.8	41.7
180°·sec ⁻¹	Control	80.2	24.7	91.7	23.0	96.6	23.9
180°·sec ⁻¹	Treatment	72.4	34.1	82.9	35.8	88.6	40.1
240°·sec ⁻¹	Control	62.3	19.9	75.5	19.8	80.6	18.8
240°·sec ⁻¹	Treatment	57.7	26.6	66.6	28.0	78.1	36.1
300°·sec ⁻¹	Control	61.1	22.4	66.6	21.2	75.9	19.5
300°·sec ⁻¹	Treatment	51.7	27.9	60.8	23.5	70.3	31.7

Note. °sec⁻¹ = °second⁻¹; Pre = Pre-test; PFT = Pre-familiarization test; Post = Post-test

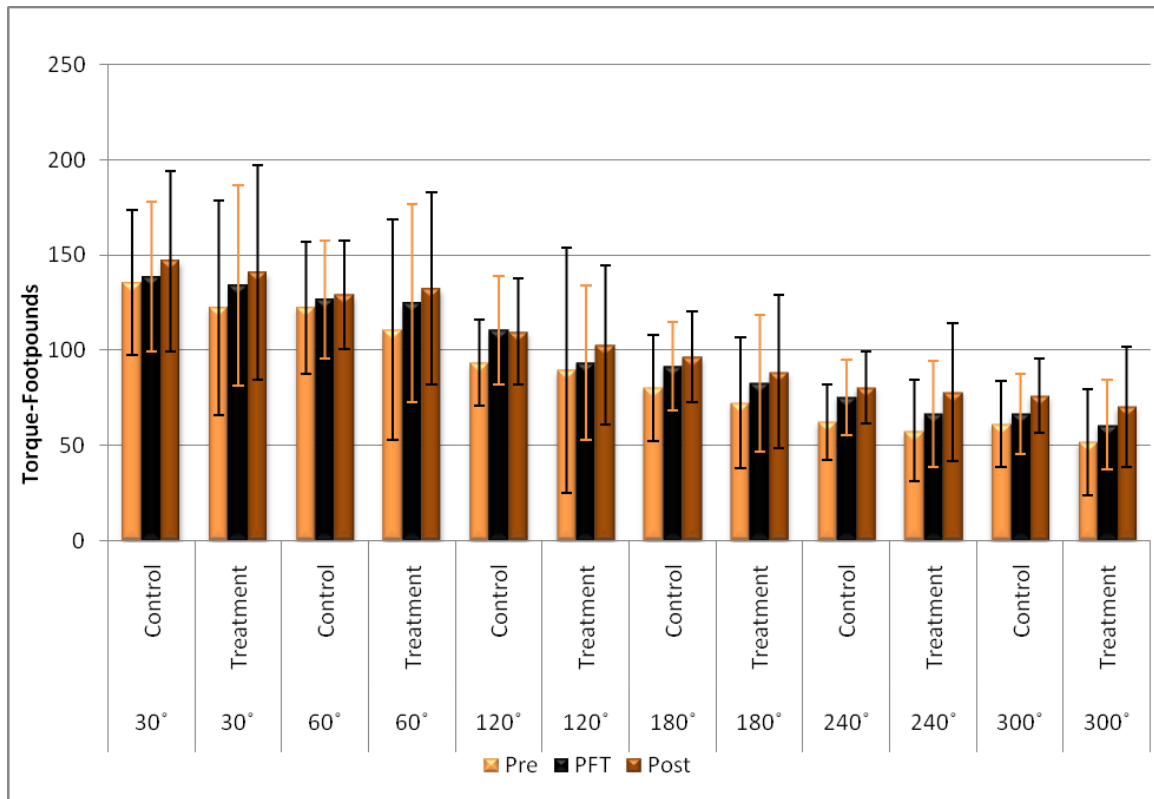


Figure 2 – Means and standard deviations of torque outputs for both groups over time
 Note. 30° = 30°second⁻¹; 60° = 60°second⁻¹;...300° = 300°second⁻¹

Since the main effect of time was the sole significant effect, time was the only element analyzed using Doubly Multivariate Analysis of Repeated Measures for each dependent variable and their time contrasts. Additionally, since there were no significant interactions or group effects, each dependent variable and associated time contrasts were run combining both control and treatment groups' data. Thus, six (Velocities) 1 x 3 (Combined Groups x Time) Doubly Multivariate Analysis of Repeated Measures were used within the MANOVA analysis. To view the effects of time with the corresponding time contrasts at each velocity, see Table 5. To view the means and standard deviations for the combined groups across all times and velocities, see Figure 3.

The only instances where groups were separated for ANOVA repeated measures analysis were for the treatment group from Pre-test to PFT at 30, 60, and 120°·sec⁻¹ (Hypothesis 1), as well as, PFT to Post-test at 180°·sec⁻¹, 240°·sec⁻¹, and 300°·sec⁻¹ (Hypothesis 2), and the control group PFT to Post-test at 240°·sec⁻¹ and 300°·sec⁻¹ (Hypothesis 3).

Slower velocities - 30 and 60°·second⁻¹

Results from the Doubly Multivariate Analysis of Repeated Measures at 30°·sec⁻¹ showed there was a significant increase in torque over time with Wilks' Lambda = 0.578, $F(2, 19) = 6.92, p = 0.0055$. Post hoc time contrasts revealed significant torque increases from Pre-test to PFT and from PFT to Post-test with $F(1, 20) = 6.19, p = 0.0218$ and $F(1, 20) = 7.64, p = 0.0120$ respectively. Similarly, at 60°·sec⁻¹ there was a significant time effect with Wilks' Lambda = 0.582, $F(2, 19) = 6.81, p = 0.0059$. However, contrasts from Pre-test to PFT were not significant with $F(1, 20) = 3.32, p = 0.0836$. The significant increase in torque was found from PFT to Post-test ($F(1, 20) = 9.78, p = 0.0053$).

Intermediate velocities - 120 and 180°·second⁻¹

At 120°·sec⁻¹, the main effect of time was significant ($p = 0.0104$) with Wilks' Lambda = 0.618, $F(2, 19) = 5.87$. The contrast from Pre-test to PFT was significant with $F(1, 20) = 7.62, p = 0.0121$. Conversely from PFT to Post-test, there was not a significant change in torque $F(1,20) = 2.62, p = 0.1211$. At 180°·sec⁻¹ there was a significant time effect ($p = 0.002$) with Wilk's Lambda = 0.521, $F(2, 19) = 8.73$. Both

Pre-testing to PFT and PFT to Post-testing time frames showed significant increases in torque ($F(1, 20) = 6.80, p = 0.0168$ and $F(1,20) = 5.49, p = 0.0296$ respectively).

Fast velocities - 240 and 300°·second⁻¹

As with the previous velocities, there were significant main effects for time at both 240 and 300°·sec⁻¹. At 240°·sec⁻¹, Wilk’s Lambda = 0.404, $F(2, 19) = 14.0$ with $p = 0.0002$. Time contrasts for torque changes at 240°·sec⁻¹ were significant from both Pre-test to PFT and PFT to Post-test ($F(1, 20) = 15.08, p = 0.0009$ and $F(1, 20) = 11.43, p = 0.003$ respectively). At 300°·sec⁻¹ Wilk’s Lambda = 0.435, $F(2, 19) = 12.31$ with $p = 0.0004$. Contrasts were also significant for Pre-test to PFT and PFT to Post-test ($F(1, 20) = 7.81, p = 0.0112$ and $F(1,20) = 7.08, p = 0.015$) respectively.

Table 5

Doubly MANOVA of Repeated Measures for Time

	<i>Time Effect</i>	<i>Pre-PFT</i>	<i>PFT-Post</i>
<i>30°·sec⁻¹</i>	F= 6.92; p=0.0055*	F= 6.19; p=0.021*	F= 7.64; p=0.0120*
<i>60°·sec⁻¹</i>	F=6.81; p=0.0059*	F=3.32; p=0.0836	F=9.78; p=0.0053*
<i>120°·sec⁻¹</i>	F=5.87; p=0.0104*	F=7.62; p=0.0121*	F=2.62; p=0.1211
<i>180°·sec⁻¹</i>	F=8.73; p=0.002*	F=6.80; p=0.0168*	F=5.49; p=0.0296*
<i>240°·sec⁻¹</i>	F=14.00; p=0.0002*	F=15.08; p=0.0009*	F=11.43; p=0.0030*
<i>300°·sec⁻¹</i>	F=12.31; p=0.0004*	F=7.81; p=0.0112*	F=7.08; p=0.0150*

Note. * p<0.05

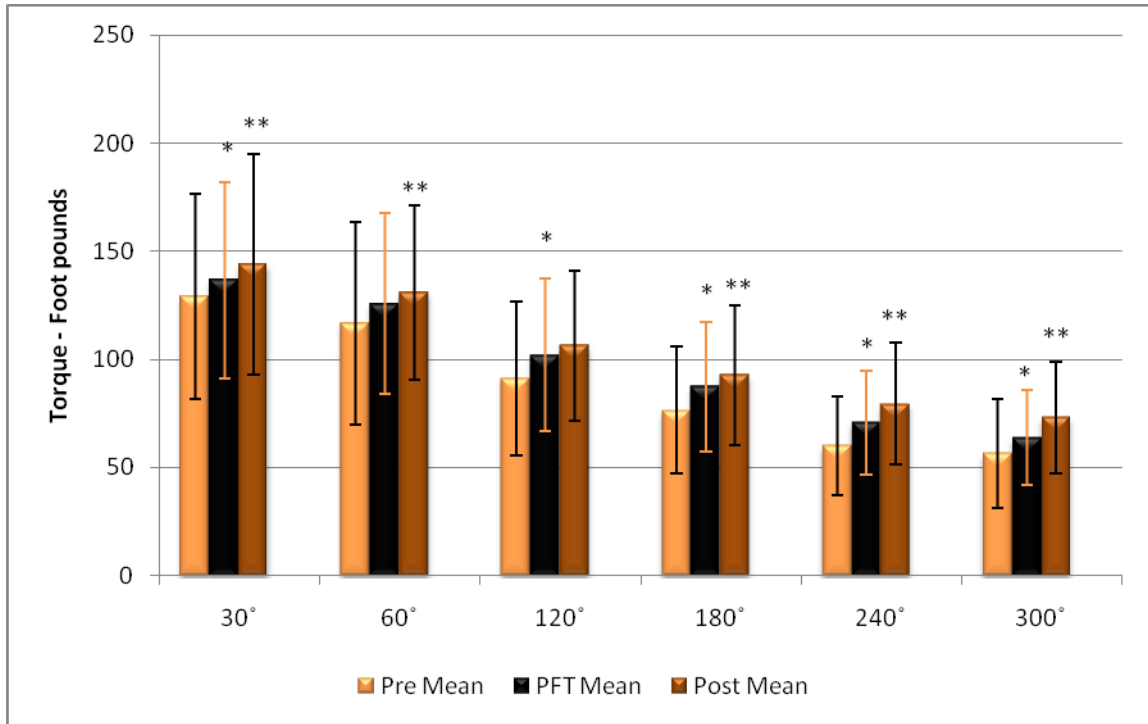


Figure 3 – Mean torque outputs for combined groups over time

Note. *=significant change ($p < 0.05$) Pre-PFT; **=significant change ($p < 0.05$) PFT-Post

Because there was a significant time effect from Pre-test to PFT at $30^\circ \cdot \text{sec}^{-1}$, the treatment group was separated out and three 1×2 (Treatment Group x Time) repeated measures were performed in order to answer hypothesis 1. The treatment group did not increase torque from Pre-test to PFT at $60^\circ \cdot \text{sec}^{-1}$ and $120^\circ \cdot \text{sec}^{-1}$; although, at $30^\circ \cdot \text{sec}^{-1}$ there appeared to be a significant increase, $F(1,10) = 6.375, p = .03$. However, since the Bonferroni adjustment was used due to the fact that three separate univariates were run on the same group; significance was adjusted to $0.05/3 = 0.017$. Because $p = .03$, then significance was not reached for $30^\circ \cdot \text{sec}^{-1}$ either. Therefore, we fail to reject the null hypothesis for hypothesis 1. To view treatment group's means and standard deviations see Figure 2.

Because there was a significant time effect from PFT to Post-testing at 180, 240, and 300°·sec⁻¹, groups were separated and five 1 x 2 (Group x Time) repeated measures ANOVA's were executed in order to answer Hypothesis 2 and 3. Of these five, three 1 x 2 repeated measures were performed for the treatment group at 180, 240, and 300°·sec⁻¹ (Hypothesis 2), and two 1 x 2 repeated measures were conducted for the control group at 240, and 300°·sec⁻¹ (Hypothesis 3). To view these group changes, see Figure 4.

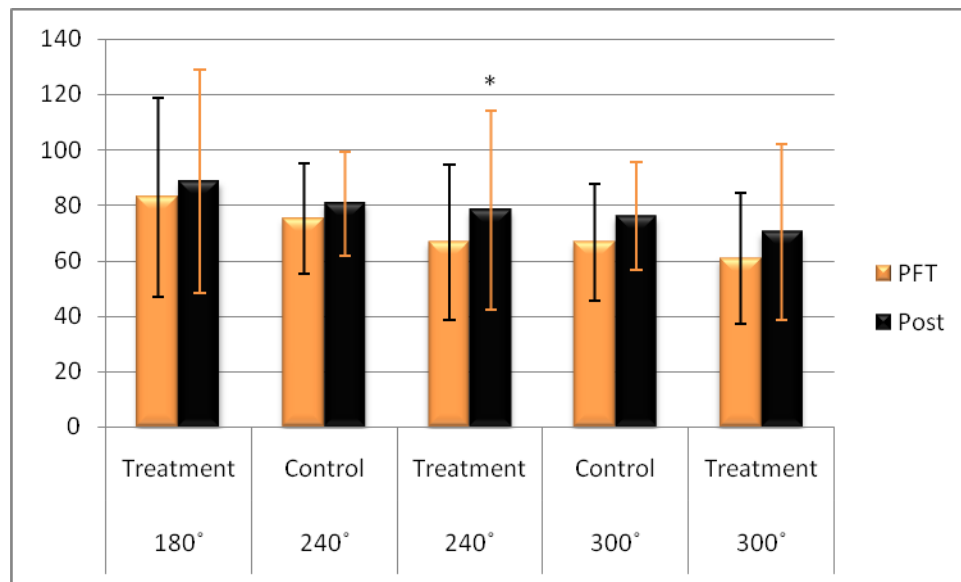


Figure 4 – Mean torque outputs Treatment and Control Groups

Note. *=significant change ($p < 0.05$) PFT-Post

For the treatment group, there were no significant increases in torque from PFT to Post-test at 180°·sec⁻¹ and 300°·sec⁻¹ with $F(1,10) = 2.66$, $p = 0.134$ and $F(1,10) = 3.97$, $p = 0.074$ respectively. However, there was a significant increase at 240°·sec⁻¹ even with Bonferroni adjustment, with $F(1,10) = 8.58$, $p = 0.015$. Therefore, the Null Hypothesis is not rejected, from Hypothesis 2, at 180 and 300°·sec⁻¹. Conversely, the Null Hypothesis

is rejected at $240^{\circ}\cdot\text{sec}^{-1}$. Hypothesis 2 stated that the treatment group would change torque output from PFT to Post-test at 180, 240, and $300^{\circ}\cdot\text{sec}^{-1}$.

When analyzing Hypothesis 3, that the control group would increase torque from PFT to Post-test at $240^{\circ}\cdot\text{sec}^{-1}$ and $300^{\circ}\cdot\text{sec}^{-1}$, we fail to reject the Null Hypothesis because there were no significant changes at either velocity with $F(1,10) = 3.064$, $p = 0.111$; and $F(1,10) = 3.184$, $p = 0.105$, respectively. Therefore, it appears the familiarization period was not a strong enough stimulus to induce significant increases in torque at the higher velocities.

As previously mentioned, with the absence of significant main group and interaction effects, we fail to reject the Null Hypothesis for Hypothesis 4 stating that there would be significant differences between the experimental and control groups' maximal torque at the three slower velocities ($30^{\circ}\cdot\text{sec}^{-1}$, $60^{\circ}\cdot\text{sec}^{-1}$, and $120^{\circ}\cdot\text{sec}^{-1}$) during the PFT. For the same reason, we reject Hypothesis 5 (or fail to reject the Null Hypothesis) that the treatment group will produce significantly greater torque, compared to the control group, at all six ($30^{\circ}\cdot\text{sec}^{-1}$, $60^{\circ}\cdot\text{sec}^{-1}$, $120^{\circ}\cdot\text{sec}^{-1}$, $180^{\circ}\cdot\text{sec}^{-1}$, $240^{\circ}\cdot\text{sec}^{-1}$, and $300^{\circ}\cdot\text{sec}^{-1}$) velocities at Post-test.

CHAPTER V

CONCLUSION

Time Effect

As indicated by the results of this study, the main effect was time. In fact, of the 12 different time intervals measured for changes in torque output (Six Pre to PFT and six PFT to Post-tests); ten of them showed significant increases in torque when both groups were combined. Therefore, it appears that with one day of practice sets at all six velocities, and one day of three maximal efforts per velocity (Pre-testing), maximal increases in torque occur regardless of whether or not subjects train. The possible reason for this is the fact that isokinetic movements do not typically exist in sport and exercise; therefore, it is a novel experience for most individuals. Because there is a good chance this was a novel experience for the subjects, this could have led to the low Pre-test torque outputs. It appears that after two sessions (one practice and one testing), rapid neurological improvements might have induced greater than expected increases in torque. This finding is in agreement with Provost et al. (1999) in which significant torque improvements were seen in isokinetic knee extensions at higher velocities following two practice sessions. As with any new task, neurological improvements occur rapidly. Ultimately, the control group's increase in torque nullified any interaction with group x time torque changes.

Another possible reason for the lack of group or interaction effects was a potential flaw in equipment and how Pre-test torques were measured. Specifically, just prior to testing, the monitor would prompt subjects to “Go” by displaying a stop light that changed from red to yellow to green. Most subjects would start almost simultaneous to the green light being displayed. Not until the PFT period was this problem detected. During the PFT, suspiciously low, apparently dampened, torque values were seen. Upon instructions to “pause about one half of a second following the green light”, the subjects demonstrated substantially greater torque values. This dampened effect seemed to occur exclusively at 240 and 300°·sec⁻¹. With this flaw, a few of the control subjects actually demonstrated almost double the torque values from Pre to PFT. At no place in the manual is there mention of this apparently necessary pause, nor was there any acknowledgement of this dampened phenomenon. Therefore, it appears to be a flaw that was only detectable via time and experience with this particular equipment. Although this might have influenced group outcomes, there were still significant control group increases from PFT to Post-test in light of the resolution to the problem. Therefore, there does seem to be a powerful and rapid learning effect involved with isokinetic movement and maximal torque output.

Group Differences

With groups separated, there were 24 different time intervals measured. Of the 24 time intervals, 23 of them resulted in, whether significant or not, increases in maximal torque. The only time period where there was not a mean increase was from the control group’s PFT to Post-test at 120°·sec⁻¹. This demonstrates a distinct pattern of torque increases with varying degrees of exposure to isokinetic resistance training. Since there

were no main effects for group, we can conclude that there were no true group differences at any of the six velocities over the three time periods. With the exception of 30 and 60°·sec⁻¹, even when evaluating the percent change in mean torque by group, there did not seem to be a distinct difference.

However, from Pre to Post-test at 30°·sec⁻¹, the treatment group increased torque a total of 13.6% compared to the 8.0% increase for the control group. Since the control groups mean was 13.1 ft-lbs greater at Pre-test, the greater percent increase in the treatment group only brought the two groups' means closer together. If the groups' means been closer at the Pre-test, significant differences might have been reached.

Likewise, at 60°·sec⁻¹ the treatment group increased an impressive 17.1% compared to the control group's 5.4% increase from pre-test to post-test. At this velocity the treatment group started out with an 11.8 ft-lbs lower average; however, by the Post-test they had a 3.3 ft-lbs greater average compared to the control group.

The greater relative increases in torque at 30 and 60°·sec⁻¹ were not surprising because these were the actual and next closest training velocities for the treatment group. To view means and percent changes by group over time for all velocities, see Table 6.

Table 6

Mean percent changes by group over time

Velocity	Group	Pre	PFT	Pre-PFT	Post	PFT-Post	Pre-Post
		Mean	Mean	% Δ	Mean	% Δ	% Δ
$30^{\circ}\cdot\text{sec}^{-1}$	Control	135.5	138.8	2.4	146.9	5.6	8.0
$30^{\circ}\cdot\text{sec}^{-1}$	Treatment	122.4	134.3	8.9	140.9	4.7	13.6
$60^{\circ}\cdot\text{sec}^{-1}$	Control	122.4	126.5	3.3	129.1	2.1	5.4
$60^{\circ}\cdot\text{sec}^{-1}$	Treatment	110.8	124.7	11.2	132.4	5.9	17.1
$120^{\circ}\cdot\text{sec}^{-1}$	Control	93.2	110.6	16.6	109.7	-0.9	15.7
$120^{\circ}\cdot\text{sec}^{-1}$	Treatment	89.3	93.2	4.2	102.8	9.4	13.6
$180^{\circ}\cdot\text{sec}^{-1}$	Control	80.2	91.7	12.6	96.6	5.1	17.7
$180^{\circ}\cdot\text{sec}^{-1}$	Treatment	72.4	82.9	12.7	88.6	6.5	19.2
$240^{\circ}\cdot\text{sec}^{-1}$	Control	62.3	75.5	17.5	80.6	6.4	23.9
$240^{\circ}\cdot\text{sec}^{-1}$	Treatment	57.7	66.6	13.4	78.1	14.8	28.2
$300^{\circ}\cdot\text{sec}^{-1}$	Control	61.1	66.6	8.3	75.9	12.3	20.6
$300^{\circ}\cdot\text{sec}^{-1}$	Treatment	51.7	60.8	15.0	70.3	13.6	28.6

Note. % Δ = Mean percent change

Of considerable interest was the fact that the greatest percent increases were seen at the two highest velocities for both groups. At $240^{\circ}\cdot\text{sec}^{-1}$, the treatment and control group increased an astounding 28.2 and 23.9% respectively. These large increases were also seen at $300^{\circ}\cdot\text{sec}^{-1}$ with the treatment group increasing 28.6% and the control group 20.6%. Although some of the increase could be attributed to the “dampened” Pre-test torque outputs at the higher velocities, there were still large percent increases from PFT to Post-test when the problem had been rectified. With only three sessions of 1 set of 10 repetitions per session, over a one week period, the treatment and control groups increased max torque at $300^{\circ}\cdot\text{sec}^{-1}$ 13.6 and 12.3% respectively. This is in further

agreement with Prevost et al. (1999) findings of large increases in max torque output at higher velocities.

Two likely reasons that there were no group differences and interactions over the three time periods could have been: the sample size for each group were too small, and training for seven week might not be long enough to induce a significant treatment effect. With only 11 subjects per group, there was a decrease in statistical power to detect group differences. Additionally, greater mean differences might have been detected had the treatment duration been longer than seven weeks. This is due to the fact that longer training periods are usually accompanied by greater muscle hypertrophy leading to larger increases in maximal torque.

General vs. Specific Adaptations

As was indicated earlier, there has been a lot of conflicting research on the principle of specificity in regards to velocity of movement. While several studies support the notion that the velocity of movement individuals train at result in increases in torque close to or at those specific velocities (Aagaard, Simonsen, Trolle, Bangsbo, & Klausen, 1996; Grimby, Hannerz, & Hedman, 1981; Hakkinen & Komi, 1985; Hakkinen, Komi, & Allen, 1985b; Iossifidou, Baltzopoulos, & Giakas, 2005; Kanehisa & Miyashita, 1983a; Kanehisa & Miyashita, 1983b; Kaneko, Fuchimoto, Toji, & Suei, 1983; McDouagh, Hayward, & Davies, 1983; Moritani & Muro, 1987; Morrissey, Harman, & Johnson, 1995; Newman, Tarpinning, & Marino, 2004; Peterson, Miller, & Wenger, 1984; Pousson, Amiridis, Comette, & Van Hoecke, 1999; Schmidtbleicher & Haralambie, 1981), other studies support more general increases in torque (Aagaard, Simonsen,

Trolle, Bangsbo, & Klausen, 1994; Adyanju, Crews, & Meadors, 1983; Behm D. , 1991; Bell, Petersen, MacLean, Reid, & Quinney³⁰, 1992; Bell, Snyder, Neary, & Quinney, 1989; Caiozzo, Perrine, & Edgerton, 1981; Colliander & Tesch, 1990; Housh & Housh, 1993; Hunter & Culpepper, 1995; Jones, Hunter, Fleisig, Esamilla, & Limar, 1999; Palmieri, 1987; Pipes & Wilmore, 1975; Sale, 1988; Smith & Melton, 1981; Timm, Sep. 1987; Wenzel & Perfetto, 1992).

The results of this study indicate a general pattern of adaptations. When combining the groups, ten of the 12 time periods showed significant increases in torque. Additionally, from Pre to PFT five of the six velocities demonstrated significant increases in torque ($30^{\circ}\cdot\text{sec}^{-1}$, $120^{\circ}\cdot\text{sec}^{-1}$, $180^{\circ}\cdot\text{sec}^{-1}$, $240^{\circ}\cdot\text{sec}^{-1}$, and $300^{\circ}\cdot\text{sec}^{-1}$). The only velocity from Pre to PFT that did not show a significant increase was at $60^{\circ}\cdot\text{sec}^{-1}$; however, it was approaching significance with $p = 0.0836$. Since the treatment group had only trained at $30^{\circ}\cdot\text{sec}^{-1}$ from Pre to PFT, this is a strong indication of general adaptations. When looking at PFT to Post-test, all velocities except $120^{\circ}\cdot\text{sec}^{-1}$ showed additional significant increases in torque with both groups combined. Since both groups were provided the opportunity to become familiar with the highest velocity ($300^{\circ}\cdot\text{sec}^{-1}$) during the final week, it is not surprising that the higher velocities significantly improved during this time period. However, it is surprising to see the continued increases even at the slower velocities ($30^{\circ}\cdot\text{sec}^{-1}$ and $60^{\circ}\cdot\text{sec}^{-1}$).

A probable reason for the general adaptations incurred during this study could have been related to the fact that students were instructed to move as explosively as possible. A pattern of general adaptation that was proposed by Behm and Sale, (1993) and supported by other researchers (Almasbakk & Hoff, 1996; Jones, Hunter, Fleisig,

Esamilla, & Limar, 1999; Moss, Refsnes, Abidgaard, Nicolaysen, & Jensen, 1997), indicate that if subjects train with the intention of moving as fast as possible, regardless of the resistance and velocity of movement, increases in torque will occur at a large range of velocities.

Limitations

It should be noted that the present study incurred several limitations. As suggested earlier, with only 11 subjects in each group there was a decrease in the statistical power to detect group differences. In addition, had the duration of the training protocol been longer, there might have been greater training adaptations resulting in greater group differences. Finally, the monitor that visually “Signaled” each subject to start seemed to prompt them too early resulting in dampened Pre-test torque values. The low scores were believed to occur predominately at the higher velocities ($240^{\circ}\cdot\text{sec}^{-1}$ and $300^{\circ}\cdot\text{sec}^{-1}$). The monitor signaled subjects via displaying a stop light that changed from red to yellow to green. On green, subjects performed maximal efforts. By the PFT testing period it became evident that a slight pause resulted in substantially higher torque values when testing at $240^{\circ}\cdot\text{sec}^{-1}$ and $300^{\circ}\cdot\text{sec}^{-1}$. Although not a desired occurrence, the magnitude of its effects are in question because it did occur in both groups and, even after the problem was resolved, both groups still showed similar improvements.

Conclusion

Isokinetic resistance training is a method of training that maintains a constant velocity of movement while allowing for variable torque outputs. In essence, an external force in the form of a dynamometer, accommodates the resistance imposed on it in order to maintain a constant velocity throughout the range of motion. This is not a typical form

of resistance encountered in sports, exercise, or everyday life. However, with this equipment we can test torque outputs at various, predetermined velocities. Because this is such a novel movement, there is likely to be rapid improvements following brief exposure. This was seen in the present study. Both the control and treatment groups demonstrated progressive increases in torque output over two time periods. It appears that short term exposure to isokinetic resistance induces rapid and large increases in torque output. Because the increase occurred so rapidly, and in both treatment and control groups, it would most likely be due to neurological enhancements. These neurological enhancements might be manifested in the form of greater recruitment and synchronization of motor units, greater rate coding, decreased coactivation of antagonistic muscle fibers, or some combination of all four. A final interesting finding was the increase torque output occurred at all six velocities. Thus, there appears to be torque increases at multiple velocities independent of the training velocity. Therefore, the results of this study indicate a general pattern of torque enhancements at various velocities induced by one practice session and one testing session. Also, the increases in torque are independent of routine training. Additionally, the greatest improvements occurred at the highest velocities. Therefore, it appears that the rapid neurological enhancements are the most pronounced at the higher velocities. The rapid and general increases in torque are most likely due to the highly unique experience of isokinetic movements coupled with the intent to move the resistance as fast as possible which induce an array of rapid neurological enhancements.

REFERENCES

- Aagaard, P., Simonsen, E., Andersen, J., Magnusson, S., Halkjer-Kristensen, J., & Dyhre Poulsen, P. (2000). Neural inhibition during maximal eccentric and concentric quadriceps contraction: effects of resistance training. *The Journal of Applied Physiology*, *89*:2249-2257.
- Aagaard, P., Andersen, J., Dyhre-Poulsen, P., Leffers, A., Vagner, A., Magnusson, S., et al. (2001). A mechanism for increased contractile strength of human pennate muscle in response to strength training: changes in muscle architecture. *The Journal of Physiology*, *534*(2):613-623.
- Aagaard, P., Simonsen, E., Andersen, J., Magnusson, P., & Dyhre-Poulsen, P. (2002). Neural adaptation to resistance training: changes in evoked V-wave and H-reflex responses. *The Journal of Applied Physiology*, *92*:2309-2318.
- Aagaard, P., Simonsen, E., Trolle, M., Bangsbo, J., & Klausen, K. (1996). Specificity of training velocity and training load on gains in isokinetic knee joint strength. *Acta Physiologica Scandinavica*, *156*:123-129.
- Aagaard, P., Simonsen, E., Trolle, M., Bangsbo, J., & Klausen, K. (1994). Effects of different strength training regimes on moment and power generation during dynamic knee extensions. *European Journal of Applied Physiology*, *69*:382-386.
- Adeyanju, K., Crews, T., & Meadors, W. (1983). Effects of two speeds of isokinetic training on muscular strength, power, and endurance. *Journal of Sports Medicine*, *23*:352-356.
- Almasbakk, B., & Hoff, J. (1996). Coordination, the determinant of velocity specificity. *Journal of Applied Physiology*, *80*:2046-2052.

- Amirdis, I., Martin, A., Morion, B., Martin, L., Cometti, G., Pousson, M., et al. (1996). Co-activation and tension-regulating phenomena during isokinetic knee extension in sedentary and highly skilled humans. *European Journal of Applied Physiology*, 73:149-156.
- Andersen, L., Andersen, J., Magnusson, S., Suetta, C., Madsen, J., Christensen, L., et al. (2005). Changes in the human muscle force-velocity relationship in response to resistance training and subsequent detraining. *Journal of Applied Physiology*, 99:87-94.
- Behm, D. (1991). An analysis of intermediate speed resistance exercises for velocity specific strength gains. *Journal of Applied Sport Science Research*, 5(1):1-5.
- Behm, D. (1995). Neuromuscular implications and applications of resistance training. *Journal of Strength and Conditioning Research*, 9(4):264-274.
- Behm, D., & Sale, D. (1993). Intended rather than actual movement velocity determines velocity-specific training response. *Journal of Applied Physiology*, 74(1):359-368.
- Bell, G., Petersen, S., MacLean, I., Reid, D., & Quinney, H. (1992). Effect of high velocity resistance training on peak torque, cross sectional area and myofibrillar ATPase activity. *The Journal of Sports Medicine and Physical Fitness*, 32(1):10-18.
- Bell, G., Snyder, S., Neary, P., & Quinney, H. (1989). The effect of high and low velocity resistance training on anaerobic power output in cyclists. *Journal of Human Movement Studies*, 16:173-181.
- Blazevich, A., & Jenkins, D. (2002). Effect of the movement speed of resistance training exercises on sprint and strength performance in concurrently training elite junior

- sprinters. *Journal of Sports Sciences*, 20:981-990.
- Caiozzo, V., Perrine, J., & Edgerton, V. (1980). Alterations in the VIVO force-velocity relationship. *Medicine and Science in Sports and Exercise*, 12:134 (abstract).
- Caiozzo, V., Perrine, J., & Edgerton, V. (1981). Training-induced alterations of the in vivo force-velocity relationship of human muscle. *Journal of Applied Physiology: Respiratory, Environmental, and Exercise Physiology*, 51(3):750-754.
- Carolan, B., & Cafarelli, E. (1992). Adaptations in coactivation after isometric resistance training. *Journal of Applied Physiology*, 73:911-917.
- Colliander, E., & Tesch, P. (1990). Responses to eccentric and concentric resistance training in females and males. *Acta Physiologica Scandinavica*, 141:149-156.
- Coyle, E., Feiring, D., Rotkis, T., Cote III, R., Roby, F., Lee, W., et al. (1981). Specificity of power improvements through slow and fast isokinetic training. *Journal of Applied Physiology: Respiratory, Environmental, and Exercise Physiology*, 51(6):1437-1442.
- Cronin, J., McNair, P., & Marshall, R. (2001). Velocity specificity, combination training and functional performance. *Journal of Science Medicine and Sport*, 4(2):168-178.
- De Luca, C., LeFever, R., McCue, M., & Xenakis, A. (1982). Behavior of human motor units in different muscles during linearly varying contractions. *The Journal of Physiology*, 329:113-128.
- Desmedt, J., & Gadaux, E. (1977). Ballistic contractions in man; Characteristic recruitment patterns of single motor units of the tibialis anterior muscle. *The Journal of Physiology*, 264:673-693.

- Desmedt, J., & Godaux, E. (1978). Ballistic contractions of slow and fast human muscle: discharge patterns of single motor units. *The Journal of Physiology*, 285:185-196.
- Ewing, J., Wolfe, D., Rogers, M., Amundson, L., & Stull, G. (1990). Effects of velocity of isokinetic training on strength, power, and quadriceps muscle fibre characteristics. *European Journal of Applied Physiology*, 61:159-162.
- Fling, B., Christie, A., & Kamen, G. (2008). Motor unit synchronization in FDI and biceps brachii muscles of strength-trained males. *Journal of Electromyography and Kinesiology*. Doi:10.1016/j.jelekin.2008.06.003
- Grimby, L., Hannerz, J., & Hedman, B. (1981). The fatigue and voluntary discharge properties of single motor units in man. *The Journal of Physiology*, 316:545-554.
- Hakkinen, K., & Komi, P. (1985). Effect of explosive type strength training on electromyographic and force production characteristics of leg extensor muscles during concentric and various stretch shortening cycle exercise. *Scandinavian Journal of Sports. Science*, 7:65-76.
- Hakkinen, K., & Komi, P. (1983). Electromyographic changes during strength training and detraining. *Medicine and Science in Sports and Exercise*, 15:455-460.
- Hakkinen, K., & Komi, P. (1986). Training induced changes in neuromuscular performance under voluntary and reflex conditions. *European Journal of Applied Physiology*, 55:147-155.
- Hakkinen, K., Alen, M., & Komi, P. (1985). Changes in isometric force- and relaxation time, electromyographic and muscle fibre characteristics of human skeletal muscle during strength training and detraining. *Acta Physiologica Scandinavica*, 125:573-585.

- Hakkinen, K., Alen, M., Kraemer, W., Gorostiaga, E., Izquierdo, M., Rusko, H., et al. (2003). Neuromuscular adaptations during concurrent strength and endurance training versus strength training. *European Journal of Applied Physiology*, 89:42-52.
- Hakkinen, K., Komi, P., & Allen, M. (1985). Effect of explosive type strength training on isometric force and relaxation time, electromyographic and muscle fibre characteristics of leg extensor muscles. *Acta Physiologica Scandinavica*, 125:587-600.
- Hakkinen, K., Komi, P., & Tesch, P. (1981). Effect of combined concentric and eccentric strength training and detraining of force-time, muscle fiber and metabolic characteristics of leg extensor muscles. *Scandinavian Journal of Sports Science*, 3(2):50-58.
- Hannerz, J., & Grimby, L. (1979). The afferent influence on the voluntary firing range of individual motor units in man. *Muscle Nerve*, 2:414-422.
- Henneman, E. (1957). Relation between size of neurons and their susceptibility to discharge. *Science*, 126:1345-1347.
- Housh, D., & Housh, T. (1993). The effects of unilateral velocity-specific concentric strength training. *Journal of Orthopaedic & Sports Physical Therapy*, 17(5):252-255.
- Hunter, G., & Culpepper, M. (1995). Joint angle specificity of fixed mass versus hydraulic resistance, knee flexion training. *Journal of Strength and Conditioning Research*, 9:13-16.
- Iossifidou, A., Baltzopoulos, V., & Giakas, G. (2005). Isokinetic knee extension and

- vertical jumping: are they related? *Journal of Sports Science*, 23(10):1121-1127.
- Jones, K., Hunter, G., Fleisig, G., Esamilla, R., & Limar, R. (1999). The effects of compensatory acceleration on the development of strength and power. *Journal of Strength and Conditioning Research*, 132:99-105.
- Kamen, G., & Knight, C. (2004). Training-related adaptations in motor unit discharge rate in young and older adults. *J Gerontol A Biol Sci Med Sci*, 59:1334-1338.
- Kanehisa, H., & Miyashita, M. (1983a). Effect of isometric and isokinetic muscle training on static strength and dynamic power. *European Journal of Applied Physiology*, 50:365-371.
- Kanehisa, H., & Miyashita, M. (1983b). Specificity of velocity in strength training. *European Journal of Applied Physiology*, 52:104-106.
- Kaneko, M., Fuchimoto, T., Toji, H., & Suei, K. (1983). Training effect of different loads on the force-velocity relationship and mechanical power output in human muscle. *Scandinavian Journal of Sports Science*, 5(2):50-55.
- Kidgell, D., Sale, M., & Semmler, J. (2006). Motor unit synchronization measured by cross-correlation is not increased with strength training on a hand muscle. *Experimental Brain Research*, 175:745-753.
- Kukulka, C., & Clamann, H. (1981). Comparison of the recruitment and discharge properties of motor units in human brachial biceps and adductor pollicis during isometric contractions. *Brain Research*, 219:45-55.
- Lesmes, G., Costill, D., Edward, F., Coyle, & Fink, W. (1978). Muscle strength and power changes during maximal isokinetic training. *Medicine and Science in Sports*, 10(4):266-269.

- Linnamo, V., Newton, R., Hakkinen, K., Komi, P., Davie, A., McGuigan, M., et al. (2000). Neuromuscular responses to explosive and heavy resistance loading. *Journal of Electromyography and Kinesiology*, 10:417-424.
- MacDougall, J., Elder, G., Sale, D., Moroz, J., & Sutton, J. (1977). Skeletal muscle hypertrophy and atrophy with respect to fibre type in humans (abstract). *Canadian Journal of Applied Sport Science*, 4(2);229.
- MacDougall, J., Sale, D., Moroz, J., & Sutton, J. (1980). Effects of strength training and immobilization on human muscle fibres. *European Journal of Applied Physiology and Occupational Physiology*, 43:25-34.
- MacDougall, J., Sale, D., Moroz, J., Elder, G., Sutton, J., & Howald, H. (1979). Mitochondrial volume density in human skeletal muscle following heavy resistance training. *Medicine and Science in Sports*, 11(2):164-166.
- MacDougall, J., Ward, G., Sale, D., & Sutton, J. (1977). Biochemical adaptation of human skeletal muscle to heavy resistance training and immobilization. *Journal of Applied Physiology: Respiratory, Environmental, and Exercise Physiology*, 43(4):700-703.
- Mann, R., & Sprague, P. (1980). A kinetic analysis of the ground leg during sprint running. *Research Quarterly for Exercise and Sport*, 60:334-338.
- Martel, G., Roth, S., Ivey, F., Lemmer, J., Tracy, B., Hurlbut, D., et al. (2006). Age and sex affect human muscle fibre adaptations to heavy-resistance strength training. *Experimental Physiology*, 91:457-464.
- McBride, J., Triplett-McBride, T., Davie, A., & Newton, R. (2002). The effect of heavy vs. light-load jump squats on the development of strength, power, and speed.

Journal of Strength and Conditioning Research, 16(1):75-82.

- Milner-Brown, H., Stein, R., & Lee, R. (1975). Synchronization of human motor units: possible roles of exercises and supraspinal reflexes. *Electroencephalography and Clinical Neurophysiology*, 38:245 -254.
- Moffroid, M., & Whipple, R. (1970). Specificity of speed exercises. *Physical Therapy*, 50(12):1692-1700.
- Moritani, T., & DeVries, H. (1979). Neural factors versus hypertrophy in the time course of muscle strength gains. *American Journal of Physical Medicine*, 58(3):115-130.
- Moritani, T., & Muro, M. (1987). Motor unit activity and surface electromyography power spectrum during increasing force of contraction. *European Journal of Applied Physiology*, 56:260-265.
- Morrissey, M., Harman, E., & Johnson, M. (1995). Resistance training modes: Specificity and effectiveness. *Medicine and Science in Sports and Exercise*, 27:648-660.
- Moss, B., Refsnes, P., Abidgaard, A., Nicolaysen, K., & Jensen, J. (1997). Effects of maximal effort strength training with different loads on dynamic strength, cross-sectional area, load-power and load-velocity relationships. *European Journal of Applied Physiology*, 75:193-199.
- Nardone, A., Romano, C., & Schieppati, E. (1989). Selective recruitment of high threshold motor units during voluntary isotonic lengthening of active muscles. *The Journal of Physiology*, 409:451-471.
- Narici, M., Roi, G., Landoni, L., Minette, A., & Cerretelli, P. (1989). Changes in force, cross-sectional area and neural activation during strength training and detraining of the human quadriceps. *European Journal of Applied Physiology*, 59:310-319.

- Newman, M., Tarpinning, M., & Marino, F. (2004). Relationships between isokinetic knee strength, single-sprint performance, and repeated-sprint ability in football players. *Journal of Strength and Conditioning Research*, 18(4):867-872.
- Palmieri, G. (1987). Weight training and repetition speed. *Journal of Applied Sport Science Research*, 12:638.
- Peterson, S., Miller, G., & Wenger, H. (1984). The acquisition of muscular strength: The influence of trainin velocity and initial VO2 max. *Canadian Journal of Applied Sport Sciences* 9(4):176-180.
- Pipes, T., & Wilmore, J. (1975). Isokinetic vs isotonic strength training in adult men. *Medicine and Science in Sports*, 7(4)262-274.
- Pousson, M., Amiridis, I., Comette, G., & Van Hoecke, J. (1999). Velocity-specific training in elbow flexors. *European Journal of Applied Physiology*, 80:367-372.
- Prevost, M., Nelson, A., & Maraj, B. (1999). The effect of two days of Velcity-Specific Isokinetic Training on Torque Production. *Journal of Strength and Conditioning Research*, 13(1):35-39.
- Pucci, A., Griffin, L., & Cararelli, E. (2006). Maximal motor unit firing rates during isometric resistance training in men. *Experimental Physiology*, 91(1):171-178
<http://ep.physoc.org/cgi/content/full/91/1/171>.
- Rich, C., & Cafarelli, E. (2000). Submaximal motor unit firing rates after 8 wk of isometric resistance training. *Medicine and Science in Sports and Exercise*, 32:190-196.
- Ritzdorf, W. (1998). Strength and power training in sport.editor. . In Elliot B, *Training in sport*. (pp. 189-237). New York: John Wiley and Sons.

- Sale, D. (1988). Neural adaptations to resistance training . *Medicine and Science in Sports and Exercise*, 20:S135-S145.
- Schmidtbleicher, D., & Haralambie, G. (1981). Changes in contractile activity properties of muscle after strength training in man. *European Journal of Applied Physiology*, 46:221-228.
- Smith, M., & Melton, P. (1981). Isokinetic versus isotonic variable resistance training. *The American Journal of sports Medicine*, 9(4):275-279.
- Tesch, P., Thorsson, A., & Kaiser, P. (1984). Muscle capillary supply and fiber type characteristics in weight and power lifters. *Journal of Applied Physiology: Respiratory, Environmental, and Exercise Physiology*, 56(1):35-38.
- Thorstensson, A. (1976). Muscle strength, fiber types and enzyme activities in man. *Acta Physiologica Scandinavica*, 443:1-45.
- Thorstensson, A., Hulten, B., von Döbeln, W., & Karlsson, J. (1976). Effect of strength training on enzyme activities and fibre characteristics in human skeletal muscle. *Acta Physiologica Scandinavica*, 96:392-398.
- Timm, K. (1987). Investigation of the physiological overflow effect from speed-specific isokinetic activity. *Journal of Orthopaedic & Sports Physical Therapy*, 9(3):106-110.
- Van Cutsem, M., Feiereisen, P., Duchateau, J., & Hainaut. (1997). Mechanical properties and behaviour of motor units in the tibialis anterior during voluntary contractions. *Can J Appl Physiol*, 22:585-597.
- Van Cutsem, M., J. D., & Hainaut, K. (1998). Changes in single motor unit behaviour

contribute to the increase in contraction speed after dynamic training in humans.

The Journal of Physiology, 513(1):295-305.

Wenzel, R., & Perfetto, E. (1992). The effects of speed versus nonspeed training in power development. *J. Appl. Sports Sci. Res*, 62:82-87.

Yao, W., Fuglevand, A., & Enoka, R. (2000). Motor-unit synchronization increases EMG amplitude and decreases force steadiness of simulated contractions. *Journal of Neurophysiology*, 83:441-452.

VITA

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Scope and Method of Study: The purpose of this study was to determine the effects of slow velocity resistance training on maximal torque output at high velocities following a brief high velocity familiarization period. Twenty two healthy college age males ($n = 9$) and females ($n = 13$) with a mean age of 22.9 ± 2.885 years old were randomly selected into either a control ($n = 11$) or treatment ($n = 11$) group. The treatment group performed 3 sets of 10 maximal repetition knee extensions with their non-dominant leg, three times per week, at $30^\circ \cdot \text{sec}^{-1}$, for seven weeks. The final week of training was accompanied by one set of 10 repetitions at $300^\circ \cdot \text{sec}^{-1}$ which was referred to as the familiarization training. The control group did not participate in the training, but did perform the familiarization sets during the final week. Both groups performed two sets of 10 repetitions at 30, 60, 120, 180, 240, and $300^\circ \cdot \text{sec}^{-1}$ as practice prior to commencing the study. Both groups were tested for maximal torque output at 30, 60, 120, 180, 240, and $300^\circ \cdot \text{sec}^{-1}$ pre, after six weeks, and post-training. A 2×3 (Group \times Time) MANOVA was conducted. Following the analysis of the overall MANOVA, interactions and main effects were assessed. If significant main effects and/or interactions occurred, time contrasts were used to determine which dependent variables contributed to the significant effect(s) at the various times. Since there were no group differences, repeated measures ANOVA was used to separate groups in order to measure changes over time within each group. Bonferroni adjustment was used when the same dependent variable was measured multiple times.

Findings and Conclusions: The results of the 2×3 (Group \times Time) MANOVA showed a significant omnibus effect with a Wilks' Lambda = 0.093, $F(6, 15) = 24.37$, $p < 0.0001$. Further MANOVA analysis showed no interaction of group \times time and no main effect for group. However, there was a significant main effect for time, $p = 0.0333$. With both groups combined, all six velocities showed significant increases in maximal torque overtime with: $30^\circ \cdot \text{sec}^{-1}$, $p = 0.0055$; $60^\circ \cdot \text{sec}^{-1}$, $p = 0.0059$; $120^\circ \cdot \text{sec}^{-1}$, $p = 0.0104$; $180^\circ \cdot \text{sec}^{-1}$, $p = 0.002$; $240^\circ \cdot \text{sec}^{-1}$, $p = 0.0002$; and $300^\circ \cdot \text{sec}^{-1}$, $p = 0.0004$. The results indicate that brief exposure to isokinetic resistance training results in rapid and general increases in maximal torque output independent of routine training. These adaptations appear greatest at higher velocities.

ADVISER'S APPROVAL: _____