KINEMATIC, NEUROMUSCULAR, AND PERFORMANCE CHANGES DUE TO OVERSPEED TRAINING FOR ICE HOCKEY

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ABSTRACT

Athletes, coaches, and strength and conditioning practitioners are constantly searching for new and improved speed training methods give themselves or their athletes an edge over their competition. Overspeed training is not a new technique of speed training; however changes and developments over the past decade have created many new methods to train at supramaximal speed. Choosing the appropriate method or methods of overspeed training is important for the training to have the desired performance improvements. High speed running and skating treadmills, tow-assisted running and skating, as well as downhill running are some of the most common methods of overspeed training. Overspeed training has been shown to improve running and skating kinematics resulting in increases in overall speed. Evaluating the benefits and negative effects of specific overspeed methods is important when selecting which methods to apply.

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TABLE OF CONTENTS

LIST OF FIGURES

CHAPTER I. INTRODUCTION

Speed is a factor in almost every sport. Elite athletes have the ability to perform game tasks at a higher speed than their competition. The development of speed is a vital component of strength and conditioning programs. In general athletes are constantly searching for any edge to make themselves elite among their competition. Coaches, practitioners, and athletes are consistently searching for new, different, and more effective methods to develop speed. In a survey by Duehring, Feldman, and Ebben (2009), 100% of high school strength and conditioning coaches incorporated some form of speed development training into their respective programs. The same survey revealed that the high-school strength and conditioning coaches surveyed incorporated training for speed development an average of 2.17 days per week. Of the high school strength and conditioning coaches surveyed by Duehring et al. (2009), over half reported using some form of overspeed running in their speed specific training. Survey results such as those by Duehring et al., highlight the interest of the athletic population in regards to speed development as well as show the popularity of the use of overspeed methods to develop speed. Research in the area of overspeed training is scarce. Many tactics used to train athletes in overspeed may or may not be appropriate for the sport or athletes being trained. The information presented in this literature review, on the most common means of overspeed training, may be an effective resource tool for practitioners to select the appropriate overspeed device for the athletes they train.

Overspeed training, also referred to as supramaximal training or assisted training, has been used for years within the realms of track and field as sport specific training. Sport specific, or sometimes labeled, functional training has become common practice for strength and conditioning professionals as it is generally accepted that using training movements more specific to competitive movements has a greater transfer of training effect to performance (Randell, Cronin, Keogh, & Gill, 2010). Training to develop increased speed in sport specific movements is the foundation of functional training. The use of overspeed training has expanded into almost all sports and training realms. Overspeed training has been found to affect sprint running kinematics differently across the many methods used to develop supramaximal speed. Commonly studied running kinematics that affect speed are stride frequency, and stride length. Many studies have identified both stride rate and stride frequency as kinematic variables that have an effect on speed. Ground force reaction (GFR) is a running kinetic variable that also affects speed. Changes in stride length and stride frequency may also affect GFR. According to Cissik (2005), the overspeed training theory allows the athlete's body to learn how to move at greater stride frequencies which is later transferred to non-assisted dry-land sprints. However, many studies, including those by Corn and Knudson (2003) and Clark et al. (2009), found that acute and chronic increases in stride length, not stride frequency, have a greater contribution to the increased horizontal velocity associated with overspeed training. A study of downhill overspeed running by Chen, Nosaka, and Tu (2007) concluded that over-speed training contributes to increases in the kinematic efficiency of runners. Despite information on how both stride length and stride frequency can effect speed, Weyand, Sternlight, Bellizzi, and Wright (2000) found GFR to be the greatest determinant of speed. Whatever the specific effects of overspeed training, findings that overspeed training may help to adapt the body to allow for increased speed output as well as increase mechanical efficiency has resulted in the use of overspeed training by many strength coaches, coaches, and athletes. The following literature evaluates the kinematics, effectiveness, and safety of the use of overspeed training to develop increases in speed and acceleration.

Purpose of the Paper

The purpose of this literature review is to compile and review current research on the positive and negative effects of overspeed training for athletes. This review will compare and contrast the most common methods of overspeed training in use across different sport and performance parameters with considerations for different age groups, ability levels, and risk of injury.

The secondary purpose of this review is to compile studied parameters for the safe and effective use of overspeed training mediums across different age groups, abilities, and sports. These parameters will aid in the choosing of the most effective and safe use of an overspeed training method in conjunction with an appropriate periodized strength and speed development program.

Methods and Procedures

To begin the review process, a comprehensive search of current literature related to overspeed training was completed. Journals and online databases with a focus in sports medicine, applied physiology, sport science, as well as strength and conditioning were investigated. Following the collection of current literature an analysis and interpretation of the literature was formed in a graduate paper format as well as in the format of the *Strength and Conditioning Journal*.

Significance of Review

The following paper will compare and contrast different overspeed devices and techniques currently used by clinicians to develop maximal speed in athletes. Kinetic and kinematic variables will be examined with the use of each overspeed method and device to compare and contrast the safety and effectiveness of each. The examination of this information will be useful for clinicians for the appropriate implementation of overspeed training methods within the bounds of sport and individual specific strength and conditioning programs.

Limitations

Possible limitations pertaining to the research of overspeed training include but are not limited to the following items:

1. There is a general insufficiency of research in the field of overspeed training.
2. There is an insufficiency of research in the use of different overspeed devices.
3. There are many inconsistencies in test to retest conditions due to environmental, physical, and social influences of speed training methods.
4. Research in overspeed training is focused on a few general movements and does not represent the multitude of functional movements in athletics.
5. Small sample sizes were used in many studies.
6. A number of studies had high rates of subject dropout.
7. Biased study participants were used in many studies due to the availability of athletically trained athletes with experience in many methods of physical training.
8. Short study duration limited the significance of the long term effects of the overspeed training method examined.

Organization of Subsequent Chapters

The second chapter is the complete literature review. The review is a compilation of the latest literature on the use and effectiveness of overspeed training. This review includes multiple devices used to achieve overspeed training as well as overspeed training over various athletic motions and sports.

The third chapter will be the introduction, literature review, as well as conclusions and a developed list of safety and performance parameters for overspeed training formatted for the *Strength and Conditioning Journal.* These parameters will not only be used to prevent injury in individuals who perform overspeed training but they will also help establish criteria to implement overspeed training in strength and speed programs.

Definitions

Concentric Muscle Contraction - Muscle action where the muscle shortens (Wilmore & Costill, 2004).

Delayed Onset Muscle Soreness (DOMS) - Muscle soreness that develops a day or two after a heavy bout of exercise and that is associated with actual injury within the muscle (Wilmore & Costill, 2004).

Eccentric Muscle Contraction - Muscle action where the muscle lengthens (Wilmore & Costill, 2004).

Kinematics - The body's movement as a result of kinetics (Holm et al., 2008).

Kinetics - The causes of motion (Holm, Stalmon, Keogh, & Cronin, 2008).

Mechanical Efficiency - The amount of energy required to perform a task in relation to the actual work accomplished (Chen, Nogasaka, & Tu, 2007).

Motor Unit - The motor nerve and the group of muscle fibers it innervates (Wilmore & Costill, 2004).

Overspeed Training - Training at speeds faster than an individual is normally capable of (Cissik, 2005).

Resistance Training - Training designed to increase strength, power, and muscular endurance (Wilmore & Costill, 2004).

Stretch-Shortening Cycle (SSC) - An eccentric and concentric combination of muscle contractions where the muscle is stretched followed by immediate contraction producing a more powerful muscle contraction than concentric muscle contraction alone (Behrens & Simonson, 2011; Flanagan & Comyns, 2008).

Supramaximal Training - Training where the athlete is allowed to move faster than normally possible by the use of a device (Kristensen, Tillaar, & Ettema, 2006).

CHAPTER II. REVIEW OF LITERATURE

Methods Used to Develop Supramaximal Speed

There are many methods used to achieve supramaximal speed in physical training. Chen, Nogasaka, & Tu (2007) and Gottschall and Kram (2004), used varying degrees of wedges under the rear of a treadmill to create a negative angle simulating a consistent downhill slope. High-speed treadmills can also be used at varying degrees of elevation with a spotter to assist the athlete's body to safely train at overspeed (Hauschildt, 2010; Swanson & Caldwell, 2000). Towing devices were used to achieve supramaximal dry-land sprint speed in studies by Clark et al. (2009), Corn & Knudson (2003), Kristensen, Tillar & Ettema (2006) as well as Leblanc and Gervais (2004). Paradisis & Cook (2006) studied dry-land supramaximal sprint speed that was developed with a downhill slope platform. Similarly Baron et al. (2009), Ebben (2008), and Ebben , Davies, and Clewien (2008) used different degree's of slope in a natural environment to develop supramaximal speed through downhill sprinting. Thomas, De Vito, and Macaluso (2007) used a pneumatic body weight unloading system to allow participants to achieve a higher treadmill speed than possible if participants were full weight bearing. Whatever method used to achieve supramaximal speed, the magnitude of the assisted force should be considered to develop speeds that are feasible to be reached later without assistance, as well as for safety purposes.

Neuromuscular Changes Associated with Overspeed Training

At the neuromuscular level, improvements in speed come from improvements in muscle strength and muscle power (a combination of strength and speed) as well as muscle coordination. For improvements in muscle strength, power, and/or coordination to occur as a result of overspeed training, constructive neuromuscular adaptations must develop within the trained muscles. Commonly accepted neuromuscular adaptations to physical training are muscle hypertrophy, increased motor unit recruitment, greater muscle force production, and increased efficiency in motor unit synchronization (Baron et al., 2009; Behm et al., 1995; Chen et al., 2007; Farthing & Chilibeck, 2003). Motor units are bundles of muscle fibers that are innervated by a motor nerve and when stimulated the result is muscle contractions (Wilmore & Costill, 2004). According to Coyle et al. (1981), increases in muscle fiber diameter (muscle hypertrophy), increases in the number of active nerves stimulating neuromuscular junctions also known as motor units, and the effective synchronization of motor units are three factors potentially responsible for the increased power-generating ability of the contractile mass of the muscle. More specifically, Behm (1995) found when using high speed training an increase in the frequency of motor unit firing occurred. An increase in the frequency of motor unit firing would lead to an increased rate of force output associated with the rate of muscle contraction which is an increase in motor unit synchronization**.** Increasing the mechanical efficiency of running form can be attributed to neuromuscular improvements in motor unit synchronization as well as increases in physical strength and power production (Hauschildt, 2010). Similarly Coyle et al. (1981) stated that physiological adaptations responsible for training-induced improvements in neuromuscular power are generally believed to occur within the trained muscle and/or the nervous system. Farthing and Chilibeck (2003), as well as Coyle et al., found that high-velocity training using lengthening muscle contractions (eccentric contraction) is most effective for increasing muscle hypertrophy when compared to low-velocity eccentric training and both high- and low-velocity shortening muscle contractions (concentric contraction) training. Downhill running kinematics have a greater amount of eccentric, high velocity, muscle contraction when compared to level surface and uphill running (Baron, 2009; Chen, 2007; Gottschall & Kram, 2005; Paradisis & Cooke, 2006). Both Coyle et al. and Farthing and Chilibeck (2003) observed a carry-over effect only from high-velocity training to performance at slower velocities reinforcing the use of downhill running, tow assist overspeed, and high speed treadmill overspeed training. Farthing and Chilibeck found no carry-over effect of low-velocity training compared to training at high-velocities. According to Farthing and Chilibeck, the mechanism for greater hypertrophy occurring as a result of eccentric high-velocity training may be a result of an increased amount of muscle damage and protein degradation associated with lengthening contractions causing a greater repair response increasing fiber size. Chen et al. (2007) found similar muscle damage in participants of 30 minute downhill running at 70% peak aerobic power. Despite the possibilities of muscle damage, Farthing, and Chilibeck concluded that fast-velocity isokinetic training is more effective than slow-velocity eccentric, slow-velocity concentric or fast-velocity concentric muscle training for strength development as well as muscle hypertrophy. The previous findings by Chen et al., Coyle et al., and Farthing and Chilibeck support the use of downhill running, tow assist overspeed and high speed treadmill overspeed training as effective methods to create positive neuromuscular changes due to the high-velocity nature of the training.

Neuromuscular improvements caused by tow assist running and skating are less attributed to muscle hypertrophy and are more directly influenced by motor unit synchronization and increased load capacity of the muscle during the stretch-shortening cycle (Behrens & Simonson, 2011; Flanagan & Comyns, 2008). The stretch-shortening cycle (SSC) is an eccentric and concentric combination of muscle contractions where the muscle is stretched followed by immediate contraction producing a more powerful muscle contraction than concentric muscle contraction alone (Behrens & Simonson, 2011; Flanagan & Thomas, 2008). Multiple training sessions with tow assist overspeed training should allow the athlete to develop an increased stride length and/or stride frequency due to the neuromuscular adaptions of the SSC and motor unit synchronization.

Kinematics of Overspeed Training

Functional training for sport focuses on development of efficient kinematics, whether the sport requires running, swimming, skating, or biking. A major concern of the efficacy of the use of overspeed training is that overspeed conditions may reinforce or create improper movement kinematics resulting in creating poor mechanical movement patterns. Speed or horizontal velocity in running is the product of the two running kinematics, stride length and stride frequency. To increase horizontal velocity (speed) an increase in stride length or stride frequency or a combination where the increase in either stride length or stride frequency is greater than the decrease in the other variable (Leblanc & Gervais, 2004). Running downhill or being towed at supramaximal speeds has been shown to create a longer "flight time," or time when the body is not in contact with the running surface, then when running without assistance at maximal or submaximal speed (Clark et al., 2009; Paradisis & Cooke, 2006). Increases in flight time have been found to be correlated to increases in stride length when using a tow assist method of overspeed training (Clark et al., 2009; Paradisis & Cooke, 2006). To accommodate for supramaximal speed, negative increases in stride length, stride frequency, and anterior pelvic tilt can be exacerbated by increasing the magnitude of assistance such as increasing the towing force, degree of slope or speed of a treadmill belt (Blazevich, 2000; Clark et al., 2009; Corn & Knudson, 2003; Hauschild, 2010).

Kinematic and Performance Changes with a Tow-System

Kinematic assessment of supramaximal dry-land sprinting using a movable weight that is affected by gravity, thus towing runners to overspeed, was studied by Kristensen et al. (2006) and Leblanc and Gervais (2004). Kinematic assessment of elastic band supramaximal sprinting tow-systems was studied by Corn and Knudson (2003), as well as Clark et al. (2009). Both movable weight and elastic tow systems have the ability to change magnitude of propulsion as well as adjust the distance of tow. The gravity activated movable weight system provides a consistent towing magnitude throughout the duration of the sprint whereas the physical properties of elastic bands create a condition where the magnitude of the propulsion is greatest at the start of the sprint and decreases as the band shortens. The before mentioned difference in consistency of propulsion between movable weight and elastic band tow systems contributes to findings of varying horizontal velocities as well as running kinematics across the training distance when similar tow forces are considered. The propulsive force was secured to the subject using a waist belt with physical connection near the navel affecting the center of mass of each subject in the same way. The movable weight tow- assist systems used by Kristensen et al., and Leblanc and Gervais as well as the elastic band tow systems used by Corn and Knudson, and Clark et al. created higher acute horizontal sprinting velocities and decreased overall sprint times when compared within subject to non-assisted sprinting and resisted sprinting over the same distance. The studies by Corn and Knudson, Clark et al., Kristensen et al., and Leblanc and Gervais found the acute increases in horizontal velocity associated with tow-assist speed training to be influenced more by stride length than by stride frequency. Corn and Knudson found stride length to increase in overspeed towed conditions on average of 6.8% over the maximal non-assisted control group. Clark et al. and Corn and Knudson reported trends towards an increase in stride frequency, although neither study found this trend to be statistically significant. Kristensen et al. found an increase of 3.3% in acute running velocity in tow-assist conditions, with a constant propulsive force, when compared to maximal non-assist conditions. Clark et al. found an increase in acute running velocity of 1.2% to 6.1% in towed conditions over four treatment groups with towing magnitude of 2.0%, 2.8%, 3.8%, and 4.7% of the subjects' body weight. Of all previously cited tow-assist studies, Corn and Knudson reported the greatest increase in horizontal velocity, 7.1% greater than control. The high horizontal velocity improvements found in the study by Corn and Knudson could be due to the method of selecting the tow-assist magnitude in the study. The magnitude of the tow force in the study by Corn and Knudson was not chosen proportional to subjects' body weight, but rather chosen by manufacturer's recommendations of medium elastic tubing for individuals under 180 pounds and heavy elastic tubing for individuals over 180 pounds. None of the studies increased their towing force magnitude past the point where the subjects horizontal velocity decreased. It is conceivable that increases in horizontal velocity of subjects could be obtained by increasing tow-assist magnitude greater than magnitudes used in the studies by Clark et al., Corn and Knudson, Kristensen et al., and Leblanc and Gervais.

Chronic performance adaptations proposed from the results of the study by Kristensen et al. (2006), such as increases in stride length and stride frequency, were attributed to improvements in motor unit synchronization along with a more efficient running form. Both Kristensen et al. and Leblanc and Gervais (2004) concluded that assisted sprint training with a tow-system developed kinematic running patterns that were more similar to non-assisted horizontal running patterns than resistance sprint training such as pulling a sled or running with a parachute. Clark et al. (2009) took it a step further and studied the effect of different towing force magnitudes on the sprint kinematics of stride length and stride frequency. Significant increases in stride length compared to control were observed in a zone in the middle of the sprint when being towed at both 3.77 and 4.69% of body weight. However the actual tow force magnitude at the start of the race were 7.36 and 9.12% of body weight respectively, due to the properties of the elastic bands used to tow the subjects.

Based on findings of increases in stride length coinciding with increases in tow-assist magnitude in the study, Clark et al. (2009) developed the following calculation for coaches and practitioners to use when choosing an elastic band to use for supramaximal sprint training. The percentage of body weight elastic band should equal the elastic bands force at 100% elongation divided by the subjects body weight multiplied by 100. This formula was developed to replace two common methods cited in the study by Clark et al. This formula is an approximation of what assistance is needed for athletes to reach a productive overspeed situation. Clinicians will often need to make slight adjustments to the formula's approximation to reach optimal training conditions. Other methods used to choose tow-assist magnitude studied by Clark et al. include timing a non-assisted fifty-yard sprint and adjusting the assistance to aid the subject to record a time of 0.5 seconds faster than the non-assisted sprint time (Clark et al.). The second method is to cap the assistance so that the subject reaches 110% of his or her maximal unaided horizontal velocity (Clark et al.).

Beyond 110% maximal non-assisted velocity the athlete may react to protect him or herself by leaning back, or increase stride length to brake from overspeed (Wilmore & Costill, 2004). Similarily, Cissik (2005) suggests that athletes should not achieve speeds greater than 106-110% of their maximal non-assisted speed and that tow-assisted sprints should not cover more than 30-40 meters in distance. A trend of capping maximum tow-assist horizontal velocity at 110% of unaided maximum horizontal velocity is common among overspeed tow-assist studies. Methods to measure maximum horizontal velocity, such as radar guns, hand timing, timing systems, or the use of a assistance forecast formula, are strongly recommended from information found in tow-assist overspeed literature (Corn & Knudson, 2003; Clark et al., 2009; Kristensen et al., 2006; Leblanc and Gervais, 2004).

Kinematic Changes and Performance Changes with High-Speed Treadmill

Relatively new to the realm of overspeed training is the use of high-speed treadmills to produce supramaximal sprint conditions. High-speed treadmills have the capability to produce supramaximal speed conditions on a decline, level, or incline surface. Practitioners trained with spotting techniques can aid subjects running kinematics including maintaining pelvic neutral and knee drive while running at supramaximal speeds. Along with maintaining proper running kinematics, high-speed treadmills have been found to increase stride frequency and stride length similar to effects of tow-assist sprinting and downhill sprinting (Hauschildt, 2010).

Gottschall and Kram (2005) used a high-speed treadmill with downhill, flat, and inclined slopes to assess the ground reaction forces of treadmill running. Gottschall and Kram found that normal impact force was 54% larger for downhill running on a nine degree decline when compared with level running. The increase in impact force found during downhill treadmill running by Gottschall and Kram coincides with findings by Chen et al. (2007), and Paradisis and Cooke (2006) that found increased musculoskeletal injury, including soreness, as a result of downhill running. High-speed treadmill's may have an advantage over down hill overspeed training as high-speed treadmills are able to produce supramaximal sprint conditions at level and incline slopes reducing surface impact forces as compared to downhill running. Clinical experience, reported by Hauschildt (2010), suggests the most effective and safest mean of overspeed treadmill training was a combination of running at an elevation with a spotter with hand placement at the base of their sacrum. Swanson and Caldwell (2000) found that incline training on a treadmill creates conditions where the athlete tends to spend a greater time in the stance phase of the leg cycle forcing the legs to move through the recovery phase at a higher rate than when running on flat ground possibly leading to increases in stride frequency. Another benefit of high-speed treadmills as a medium for overspeed training is the metabolic benefits of varying the degrees of elevation during a training program to introduce the body to varying levels of lactate helping the body to develop an increased buffering capacity to lactate improving recovery time (Hauschildt). The use of high-speed treadmills for analysis of running form during overspeed training is much easier than setting up video or moving mechanisms needed for land based overspeed training (Hauschildt). The consistency of the surface of high-speed treadmills when compared to the many options for natural and indoor/outdoor surfaces creates a consistent training medium that is very accessible from day to day. However, practitioners question the transfer of performance on a treadmill surface to the playing surface of the sport the athlete participates in. Skating treadmills have been developed and continuously improved to create conditions that closely represent natural ice, but give the advantage of training in limited space at overspeed condtions. Dreger (1997) showed that skating drills completed on a skating treadmill will directly transfer to skating skill improvements on the ice. Dreger (1997) found that skating on a skating treadmill has many advantages over training on natural ice alone, and these advantages will transfer to increased performance on the ice. Overspeed conditions on skating treadmills can be created by increasing the treadmill's incline as athletes do not skate on inclined ice, as well as holding onto a bar for control at supramaximal speeds. Skating treadmills do have drawbacks, most notably, the ability to exclusively train skaters in a predominantly linear pattern.

Kinematic Changes and Performance Changes with Downhill Running

Downhill running is probably the most cost effective method used for overspeed training as well as the most popular method used to create overspeed conditions (Ebben, Davies & Clewien, 2008). Downhill running can be performed in the natural environment as well as on manufactured decline tracks. The degree of slope of the decline surface has been investigated to determine its affects on acute horizontal velocity, acceleration, foot to surface interaction, as well as sprint kinematics.

Studies by Ebben (2008), and Ebben, Davies and Clewien (2008) examined the effects of varying hill slopes on acute acceleration and horizontal velocity. These separate studies used the two different groups of subjects on nearly the same outdoor sloping surface. Ebben (2008) used varying slopes of 2.1, 3.3, 4.7, 5.8, and 6.9° over a 40 yard distance showing that the 5.8° slope condition yielded the greatest increase in speed of 1.9% Very similar were the findings of Ebben et al. (2008) with the 5.8° slope yielding a 7.09% improvement in 40 yard sprint time. Acceleration was also accounted for in the study by

Ebben et al. by checking sprint times at the 10 yard mark as well as the 40 yard mark. The greatest decrease in 10 yard sprint time compared to flat control was a 6.54% decrease found in the 5.8° of slope condition. The results from both studies show continuous improvement in horizontal velocity as slope increases from flat until slope reaches 6.9% grade where increases in sprint times and decreases in sprint velocities were shown to occur (Ebben; Ebben et al.). Both Ebben and Ebben et al. suggested that supramaximal sprint training may be more effective at slopes greater than 3° which contradicts parameters suggested by Cissik (2005) of slopes no greater than 2-3°. However the slope of 5.8° created average overspeed conditions near 106% maximum non-assisted velocity which is near what Cissik stated as a safe range of less than 106-110% maximum non-assisted velocity. As suggested before overspeed velocities greater than 110% maximum non-assisted velocities can cause negative changes in running kinematics such as braking forces of the muscles for body control (Cissik).

Unlike tow-assist overspeed training where increases in stride length occurs without an increase in stride frequency, downhill running has shown trends towards decreased stride length and increased stride frequency. (Paradisis & Cooke, 2006; Gottschall & Kram, 2005; Chen et al., 2007). The decrease in stride length and increase in stride frequency can lead to an increase in eccentric muscle action within a sprinters mechanics. Greater eccentric muscle actions can cause an increase in muscle soreness due to an increase in protein degradation within the muscles which Chen et al. highlighted as a negative effect of downhill training. Delayed onset muscle soreness (DOMS) as well as muscle hypertrophy has been linked to the increased eccentric action of muscles during downhill running (Chen et al., 2007; Gottschall & Kram, 2005). Possible injury associated with downhill running is not limited to DOMS, but other musculoskeletal injuries could occur due to the angle of foot strike during downhill running. Gottschal and Kram found that downhill running increases foot impact and braking forces transmitting these forces through the musculoskeletal system and increasing risk of injury**.** Results from the study by Chen et al. suggest that changes in running form and compromised muscle function due to muscle damage contribute to a reduction in running kinematic efficiency for three days following a bout of downhill running.

Overspeed Training as a Function of a Complete Training Program

Speed is a vital component of performance; however strength, balance, and flexibility also play major roles in an athlete's ability to perform. None of the studies suggested that overspeed training be the one singular method of training for speed development of athletes. A number of studies suggested that over-speed training should be coupled with resistance training, or resisted sprint training, to improve sprint performance (Cissik, 2005; Hauschildt, 2010; Paradisis & Cooke, 2006). Paradisis and Cooke stated that strength and form adaptations could have come from the combination of assisted and resistance sprint training methods completed in their respective studies. Whether sprinting in a race or competing within a team sport, acceleration and top speed are two different yet equally important components that an athlete should include in training. Overspeed training may only be effective for top speed training as assisted sprint training methods more closely represents maximum velocity sprint form and resistance sprint training methods more closely resembles the acceleration phase of sprinting (Leblanc & Gervais 2004; Girold et al., 2007). Only the study by Kristensen et al. (2006), found a negative relationship between resistance sprint training and non-assisted sprint performance. The use of overspeed training as a component of a functional strength and speed program may be an effective training tool for athletes competing in high speed sports.

Conclusion

The resounding question regarding overspeed training centers around the question: Does overspeed training transfer to improved performance during competition? All of the overspeed techniques discussed in this paper should provide an avenue for athletes to improve their cardiovascular fitness which should in turn, improve their performance in sport. Through their short distance high velocity protocols tow assistance overspeed training methods should help athletes increase their stride rate and/or stride length along with increases in lower body strength and/or flexibility transferring to increased performance. Running and skating high-speed treadmills are good tools for observation running and skating mechanics. More importantly, with the variability of training that can be performed on treadmills these machines should be utilized for speed improvement for almost any land based sport as well as ice hockey. Downhill running, though cost effective, may best be used in small bouts and must be carefully monitored due to the increased injury occurrence caused by the eccentric loads. Athletes with poor running mechanics or athletes with predispositions to injury should avoid downhill running. Training adaptations such as increases in strength, stride length, stride rate, ground speed, and coordination make overspeed training a practical and effective method to improve performance in ground based sports including ice hockey.

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CHAPTER III. OVERSPEED TRAINING THEORY APPLICATION AND USE FOR ICE HOCKEY

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Summary

Overspeed training has historically been used to improve sprint velocity in land based sports. Today the use of overspeed training is not limited to dry-land sports. New methods, increased awareness of overspeed training, and innovations in overspeed training equipment have expanded overspeed training into a viable training method for almost every sport, including ice hockey. Improving maximum skating velocity is highly sought after by ice hockey athletes creating a need for supramaximal speed training methods. Overspeed training on dry-land as well as on natural ice and artificial ice surfaces can help ice hockey athletes achieve higher unassisted skating velocities. Research is limited in the use and effectiveness of overspeed training for ice hockey athletes however the overspeed training theory suggests that proper on and off ice overspeed training can carry over to positive training induced improvements in maximum skating velocity. The goal of this review is to provide information about overspeed training for ice hockey athletes and its integration into ice hockey strength and conditioning programs.

Introduction

To give themselves an edge over their competition, athletes, coaches, and strength and conditioning practitioners are constantly searching for new and improved methods to increase an athlete's speed of performance. The overspeed training method creates physiological adaptations in the muscle and nervous system that result in training induced improvements to speed (Coyle et al., 1981). Overspeed training is not a new technique of speed training. However, recent changes and developments in technology have created many new methods to train at supramaximal speed opening up overspeed training to a broad range of athletes. Pneumatic devices, elastic tubing, gravity assist devices, high speed treadmills, skating treadmills and body weight unloading devices have brought the overspeed training theory to a multitude of sports and training methods. Traditionally, overspeed training has been used to increase sprint speed in land based running sports such as track and field, and football. Overspeed training has been adapted for use in many sports such as ice hockey to improve maximal skating speed. Choosing a method of supramaximal training that is appropriate for the athlete is vital for the training to have the desired effect. With the wide variety of overspeed training methods and devices available, an understanding of the desired kinematic improvements from overspeed training is necessary when choosing which method or methods to use. For example, overspeed training has been shown to improve running kinematics in some training methods as well as create or exacerbate poor kinematics in others. Evaluating the positive and negative effects of specific overspeed methods is also very important when selecting a method of overspeed training. Negative effects such as excessive eccentric loading create an increased risk of injury, which is a major concern with the use of downhill running overspeed training. Due to the possibility of injury, safety protocols have been established in regard to the use of overspeed training specifically downhill running, tow-assist overspeed training, and high speed treadmill.

High-speed treadmills may be the most effective overspeed device when used to evaluate running and skating kinematics (Dreger, 1997; Hauschildt, 2010). The ability to use a spotter or harness, and varying degrees of elevation has led to development of improved high-speed treadmills and treadmill running programs. Similar to high speed treadmill running, skating treadmills with harness systems can be used to study skating kinematics when ice hockey athletes are subjected to supramaximal conditions. High speed skating treadmills can effectively improve skating stride rate and stride frequency in ice hockey athletes (Dreger, 1997). Overspeed sprint training on dry-land, as well as on ice should carry over to an increase in skating sprint speed for ice hockey athletes making overspeed training an important facet in total body conditioning for ice hockey.

Methods to Train at Overspeed

There are many methods used to achieve supramaximal speed in physical training. Three common means of dry-land overspeed training methods are gravity assist to overspeed, tow assist to overspeed, and high speed treadmills. Chen et al. (2007) and Gottschall and Kram (2004), used varying degrees of wedges under the rear of a treadmill to create a negative angle simulating a consistent downhill slope. High-speed treadmills can also be used at varying degrees of elevation with a spotter to assist the athlete's body to safely train at overspeed (Hauschildt, 2010). Towing devices can be used to achieve supramaximal dry-land sprint speed (Clark et al. 2009; Corn & Knudson, 2003; Kristensen, Tillar & Ettema, 2006; Leblanc & Gervais, 2004). Paradisis and Cook (2006) studied dry-land supramaximal sprint speed that was developed using a downhill slope platform with a hard surface. Similarly Baron et al. (2009), Ebben (2008), and Ebben , Davies, and Clewien (2008) used different degree's of slope in a natural environment to develop supramaximal speed through downhill sprinting.

A device common to overspeed training for ice hockey over the years has been slide boards and tow assist devices such as elastic bands. Tow assist devices can be used on ice to allow the athlete to reach maximal speed and develop stride kinematics to accommodate for the high speed. Athletes with the ability to skate with a greater range of motion at the knee generally reach higher velocities than skaters who skate with straighter knee angles. Quality knee bend can also be developed through the use of high speed skating treadmills. Skating treadmills, although expensive, are becoming more common in hockey dominant geographic regions. Skating treadmills make overspeed training and conditioning available year round, and many times, are used for training when ice surfaces are not available. The benefit of a properly used skating treadmill is that it can aid in skating speed development for an athlete in and out of season.

Assisted Towing Methods

Elastic tubing is probably the most common and inexpensive device used with tow assist overspeed on-ice training (Behrens & Simonson, 2011). Other tow assist devices include pneumatic and weight assistance towing devices. Pneumatic devices use a system of pulleys attached to pressurized cylinder to created resistance in one direction or assistance in the other. Weight assist devices use the effect of gravity on a hanging stack of weights to pull a cord attached to the athlete. The main purpose of tow assist overspeed training is to force the athlete to take faster steps within a normal stride length forcing an increase in stride frequency (Behrens & Simonson, 2011). Systems such as elastic bands and gravity assisted pulley systems should not assist the athlete more than 110% of maximal unassisted sprint speed or braking will result causing unwanted changes in running kinematics (Clark, et al., 2009). Tow-assist systems have been shown to increase stride length and flight time of runners when being towed at supramaximal horizontal velocities (Corn & Knudson, 2003). Tow-assist overspeed systems have also been shown to increase the angle of pelvic tilt proportionately to the amount of tow-assist force applied. (Blazevich, 2000; Clark et al., 2009; Corn & Knudson, 2003; Hauschild, 2010).

Similar to dry land overspeed training, tow-assist systems can be used for skating to develop knee bend and control at high-speeds. Due to relatively small size of the ice surface, partner tow assist with elastic tubing may be the most viable option (Figure 1). Tow assist systems can also be used on artificial ice surfaces in addition to lateral slide board to develop knee bend as well as stride length and stride frequency improvements.

Assisted Slide Board

The lateral slide board has been used as a hockey specific dry land training device for many years. A dry land tow assist overspeed method of training specific to ice hockey is using elastic bands, pneumatic assistance, or gravity fed assistance to create overspeed conditions on a slide board.   Adding assistance to the slide board creating an overspeed situation is a new experimental method to increase an athlete's knee bend as well as an athlete's ability to absorb high speed lateral velocity and change direction (Figure 2). Constructive neuromuscular and kinematic adaptations resulting in increased power output from overspeed slide board training should carry over to increase on ice performance. The assistance pulls the athlete into the block on the slide board creating a need for greater knee bend to absorb the increased speed created across the board. The eccentric and subsequent concentric action of the knee joint to absorb and push off from the block is a fundamental movement in ice skating.

High Speed Treadmill Methods

Relatively new to the realm of overspeed training is the use of high-speed treadmills to produce supramaximal sprint conditions. High-speed treadmills have the capability to produce supramaximal speed conditions on a decline, level, or incline surface. Practitioners trained with spotting techniques can aid an athlete's running kinematics, including maintaining pelvic neutral and proper knee drive while running at supramaximal speeds (Figure 3). Along with maintaining proper running kinematics, high-speed treadmills have been found to increase stride frequency and stride length similar to effects of tow-assist sprinting and downhill sprinting (Hauschildt, 2010). Swanson and Caldwell (2000) found that incline training on a treadmill creates conditions where the athlete tends to spend a greater time in the stance phase of the leg cycle forcing the legs to move through the recovery phase at a higher rate than when running on flat ground, possibly leading to increases in stride frequency. Another benefit of high-speed treadmills for overspeed training is the metabolic benefits of varying the degrees of elevation during a training program to introduce the body to varying levels of lactate helping the body to develop an increased buffering capacity to lactate improving recovery time (Hauschildt).

Skating treadmills offer three different overspeed stimuli to the ice hockey athlete. First, high speed treadmills allow for an athlete to skate at a maximal velocity for a much longer time than skating on an ice surface. For many ice hockey players as soon as they reach maximum velocity on the ice they must slow and change direction because they run out of room within the confines of the ice rink. Skating treadmills create the overspeed scenario where skaters can maintain their maximal velocity much longer than on an ice surface. Some skaters have a greater maximal skating velocity on the treadmill as they do not have to limited distance as they would in a rink. Second, skating treadmills offer the ability to skate on a multitude of slopes while wearing a harness forcing the athlete to generate a faster stride rate and higher power output than skating on a flat ice surface. Finally, the added stability of the harness and bar system allows the athletes to achieve greater stride frequencies than straightforward maximal on ice sprinting.

Downhill Sprint Methods

Supramaximal downhill sprinting is perhaps the most common and least expensive method of overspeed training (Behrens & Simonson, 2011; Ebben, Davies, & Clewien, 2008). Of the three main overspeed methods (tow assist, high speed treadmill, and downhill running), downhill running is the least hockey specific method overspeed training. The benefits of downhill running overspeed training for ice hockey are limited to the ease of access for athletes, and the minimal cost of equipment needed for the training. When considering using downhill running for hockey specific, overspeed training practitioners must take into account the increased eccentric load produced in the muscles. Unlike tow-assist overspeed training where increases in stride length occurs without an increase in stride frequency, downhill running has shown trends towards decreased stride length and increased stride frequency (Chen et al. 2007; Gottschall & Kram, 2005; Paradisis & Cooke, 2006). The decrease in stride length and increase in stride frequency leads to the increase in eccentric muscle action. Greater eccentric muscle actions can cause an increase in muscle soreness due to an increase in protein degradation within the muscles which Chen et al. highlighted as a negative effect of downhill training. Delayed onset muscle soreness (DOMS), as well as muscle hypertrophy, has been linked to the increased eccentric action of muscles during downhill running (Chen et al., 2007; Gottschall & Kram, 2005). Possible injury associated with downhill running is not limited to DOMS. Other musculoskeletal injuries could occur due to the angle of foot strike during downhill running. Gottschal and Kram found that downhill running increases foot impact and braking forces transmitting these forces through the musculoskeletal system and increasing risk of injury. A safety limit of no more than 106-110% of maximal unassisted sprint speed has been established for the degree of slope used during downhill running (Cissik, 2005). Despite the increased risk of injury with downhill running, positive training increases in stride frequency can be attained (Chen et al. 2007; Gottschall & Kram, 2005; Paradisis & Cooke, 2006). For ice hockey athletes, downhill running may be carefully considered if tow assist, or high speed treadmill overspeed training devices are not available.

Overspeed Theory Applied to Ice Hockey

The sport of ice hockey is played with many short bursts of maximal speed. Faster athletes have a distinct advantage over slower athletes in ice hockey. With regard to skill level, hockey sense, and other hockey specific qualities, acceleration and maximal speed are critical physical qualities for the hockey athlete to excel. Training to increase maximum speed for ice hockey is done in short bursts of 30 seconds to one minute, which constitutes the typical time of a shift when the athlete is competing. Tow assist and high speed treadmill overspeed training programs follow similar protocol of short 30 second to one minute efforts followed by a short rest and repeat. Dry land overspeed training has been found to increase stride rate and stride frequency in dry land sprinting athletes (Behrens & Simonson, 2011; Cissik, 2005; Clark et al., 2009; Corn & Knudson, 2003; Ebben, 2008; Hauschildt, 2010; Paradisis & Cooke, 2006; Ross et al., 2009) Stride rate and stride frequency are kinematic traits also influential in skating maximum velocity. High speed skating treadmills offer the ability to increase athletes stride rate and stride frequency within a hockey stride including the proprioception needed for skate edge control. Although running and skating have different kinematic components, a carry over effect should occur between dry land overspeed training to on ice maximum velocity performance. The same assumption could be said about slide board overspeed training carry over to on ice performance.

Neuromuscular Improvements

At the neuromuscular level, improvements in speed come from improvements in muscle strength and muscle power (a combination of strength and speed) as well as muscle coordination. For improvements in muscle strength, power, and/or coordination to occur as a result of overspeed training, constructive neuromuscular adaptations must develop within the trained muscles. Commonly accepted neuromuscular adaptations to physical training are muscle hypertrophy, increased motor unit recruitment, and increased efficiency in motor unit synchronization (Baron, 2009; Behm, 1995; Chen, 2007; Farthing & Chilibeck 2003). Motor units are bundles of muscle fibers that are innervated by a motor nerve and when stimulated the result is muscle contractions (Wilmore & Costill, 2004). According to Coyle et al. (1981), increases in muscle fiber diameter (muscle hypertrophy), increases in the number of active nerves stimulating neuromuscular junctions also known as motor units, and the effective synchronization of motor units are three factors potentially responsible for the increased power-generating ability of the contractile mass of the muscle. More specifically, Behm (1995) found when using high speed training an increase in the frequency of motor unit firing occurred. An increase in the frequency of motor unit firing would lead to an increased rate of force output associated with the rate of muscle contraction which is an increase in motor unit synchronization**.** Increasing the mechanical efficiency of running form can be attributed to neuromuscular improvements in motor unit synchronization as well as increases in physical strength and power production (Hauschildt, 2010). Similarly Coyle et al. stated that physiological adaptations responsible for training-induced improvements in neuromuscular power are generally believed to occur within the trained muscle and/or the nervous system. Tow-assist overspeed running and skating do not have the high eccentric muscle loading component that is found in downhill running and lateral slideboard tow-assist training. Neuromuscular improvements caused by tow assist running and skating are less attributed to muscle hypertrophy and are more directly influenced by motor unit synchronization and increased load capacity of the muscle during the stretch-shortening cycle (Behrens & Simonson, 2011; Flanagan & Thomas, 2008). The stretch-shortening cycle (SSC) is an eccentric and concentric combination of muscle contractions where the muscle is stretched followed by immediate contraction producing a more powerful muscle contraction than concentric only muscle contraction. Tow-assist skating and running training create overspeed conditions where the athlete is able to develop an increased stride frequency within a longer stride length than without assistance. Multiple training sessions with tow assist overspeed training should allow an athlete to develop an increased stride length and/or stride frequency due to the aforementioned neuromuscular adapations increasing unassisted maximal sprint velocity.

Conclusions

Speed improvement is a vital part of strength and conditioning programs and athlete development in general. Elite athletes as well as novice athletes generally want to become faster; however, increasing an athlete's maximum speed is difficult to accomplish. Many kinematic shortcomings hold athletes back from reaching their maximum speed potential including inadequate stride length, inadequate stride frequency, low GFR, slow SSC, insufficient muscle strength, and poor pelvic tilt. Overspeed training methods discussed in this review have shown promise in improving one or more of each of these areas of shortcomings while safely enhancing athlete speed development. Not only can overspeed training help address kinematic shortcomings but it is also useful as a functional and safe cross training method for many sports. High-speed treadmills and indoor tow-assist overspeed systems allow athletes to train at or above maximal velocities year round in controlled environmental conditions. In many areas, ice surfaces are not available in the summer months, or are just too expensive for many athletes to train on ice year round. Overspeed training such as skating treadmill, slide board, high speed running treadmill, and other running tow-assist devices give athletes an option for speed training for ice hockey when ice time is not available. High-speed treadmill spotting techniques performed by knowledgeable practitioners is a viable method to evaluate, teach, and develop an athlete's running economy at maximal and supramaximal speeds. Finally, overspeed training has been shown to be a safe method of speed training that can be implemented into an ice hockey specific training program.

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Figure 1. Tow assist partner skating

Figure 2. Assisted slide board

Figure 3. High speed treadmill with spotter

Figure 4. Partner tow assist overspeed (rear runner)