THERMAL IMAGING AND GYMNASTICS INJURIES: A MEANS OF SCREENING AND INJURY IDENTIFICATION

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Abstract

Gymnasts have a relatively high injury rate and severity with highly qualified gymnasts suffering the most. One of the common injuries in gymnastics is the overuse-type that often remains latent until near the decisive moments of competition when the injury rises to the level of incapacitation. Is there a technology and methodology available to monitor gymnasts during development that can identify latent injuries and thus alert medical personnel to potential performance-limiting problems at the earliest possible time? Imaging consists of the use of a thermal camera to identify inflamed areas and asymmetric temperature patterns. Thermal asymmetries are determined via thermal image and pain is assessed with palpation, history, and subject identification. Video recordings are made of the involved areas and recorded electronically for transfer to physicians, physical therapists, and athletic trainers for further investigation and remediation. This is an ongoing descriptive study of the use of thermal imaging on inflammation and injury in gymnasts. Thermal differentiation of tissue areas is performed by visual inspection and bilateral comparison of the thermal images. Thermal images show bilateral and tissue area thermal differentials by differences in gray scale. This information discriminates injuries, inflammation, and other conditions without invasive procedures. The ability to identify and thus treat injuries while they are minor is a significant improvement over waiting until the injuries become increasingly symptomatic and performance-limiting. Thermal imaging has become a mainstay of our laboratory in assisting young athletes in remaining injury free, making return-to-activity decisions, and collaborating with medical personnel to identify, prevent and treat injuries and other conditions.

Keywords: *gymnastics, injuries, thermal imaging.*

INTRODUCTION

The history of modern science over the last 200 years has largely been the development of technologies that help people “see better.” Microscopes, telescopes, x-ray, magnetic resonance imaging, computerized tomography, positron emission tomography, high-speed film and video, tiny video cameras that can provide the athlete’s point of view, radar, electrocardiography, electromyography, and countless others have been responsible for a great deal of the progress of science and medicine. One of the technologies that has been used in a variety of scientific and medical settings, but appears to be relatively unknown in gymnastics, is thermography or thermal imaging. Gymnastics, with its high injury incidence and rate (Steele & White, 1986; Sands, Newman, Harner, Paulos & Shultz, 1987; Caine, Cochrane, Caine & Zemper, 1989; Sands, Shultz & Newman, 1993; De Smet, Claessens, Lefevre & Beunen, 1994; Modlesky, Nichols-Richardson, Massoni, Laing, & Lewis, 2000; Sands, 2000; Chan, Aldridge, Maffulli & Davies, 1991; Hall, 1986) is a ripe area for the application of thermography to detect and characterize inflammation and pain syndromes (Curwin, 1990; Curl, 1990; Hargreaves, 1990; Friedlaender, Jokl & Horowitz, 1990).

Thermal imaging relies on the detection of a small segment of the electromagnetic spectrum below visible light (i.e., infrared). All objects with a temperature above zero degrees Kelvin (absolute zero) emit thermal radiation. Passive thermography consists of using a special camera that is sensitive to the mid (3-5 µm) and long (7-14 µm) infrared bands of the electromagnetic spectrum. These cameras employ an algorithm that converts the invisible infrared light to visible light for display on a viewer, recorded as an image or video, and/or displayed on a computer. Infrared thermography for injury detection relies on the thermal contrast between areas of skin lying above and near the injury and the surrounding tissues. Soft-tissue trauma can easily be detected by thermographic imaging. After a soft-tissue injury, the vascular and metabolic systems change the rate and distribution of heat in the affected areas. This changes the ‘normal’ surface temperature distribution and makes any tissue thermal differences visible in infrared (Walsh & Helzer-Julin, 1990).

The measurements are highly sensitive to thermal differentials. Healthy people exhibit symmetric thermal patterns (Goodman, Heaslet, Pagliano & Rubin, 1985). Reearch has shown that an assymmetry of 1° C is abnormal (Walsh & Helzer-Julin, 1990). Detecting an already inflamed area may provide substantial additional feedback to medical, scientific, and coaching personnel as to exactly where the injured area is, and the extent of damaged tissue. From experience, athletes often wait weeks or months before seeing a physician and thereby lengthen the duration of rehabilitation (Goodman et al. 1985). Athletes often cannot pinpoint the location of all injured areas due to a perceptual bias toward the area that hurts the most. If a regular thermal screening of sensitive areas was used, the athlete may be steered to medical remediation sooner than is now typical.

Thermal imaging in the detection and treatment of injury relies on the underlying physiology of temperature differentials. Usually, dermal temperature differentials do not exceed 0.25° C., while differentials in excess of 0.65° C are consistently associated with pathology (BenEliyahu, 1997). Detection of increased or decreased dermal temperature differentials can be indicative of injury. If there is sympathetic or unmyelinated nerve involvement there will be an increase in catecholamines in the area and a vasospastic effect will occur within the local microcirculation resulting in decreased local perfusion and a colder area. Hypersensitization of alpha receptors can also result in a decreased local dermal area temperature due to denervation. Increased dermal temperatures are usually observed with acute injury due to increased vasodilatory effects and increased inflammatory mediators raising metabolism and blood flow (BenEliyahu, 1997; Curl, 1990; Leadbetter, 1990b; Curl, 1990; Leadbetter, 1990a). A French study of 200 ankle sprain patients showed that bilateral isothermia indicated a minor injury that resolved in 1 to 2 weeks. Hyperthermia showed thermal differentials unilaterally of from 1.0° to 4.0° C between the hot “injured” area and surrounding tissues. When thermal asymmetry between the ankle sprain and uninvolved ankle ranged from 1.5° to 2.0° C recovery extended to approximately four weeks (Schmitt & Guillot, 1984). Pochachevsky showed hypothermic asymmetry in ankle injuries that has been termed posttraumatic reflex sympathetic dystrophy or posttraumatic pain syndrome (Pochaczevsky, 1987). The mechanism underlying this syndromes may be efferent vasoconstriction due to afferent C-nociception from damage to the joint and surrounding structures (Pochaczevsky, 1987).

The purpose of our ongoing investigations and application of thermal imaging is to provide helpful feedback to coaches, athletes, scientists, physicians, physical therapists, and athletic trainers in preventing, assessing, and determining return to activity in athletes and others. We believe that thermography is an essential aspect for athlete screening, injury identification, and monitoring injury recovery. As such, thermography is an underutilized technology that may help gymnasts prevent injury via early recognition and early entrance into the medical system (Holst, 2000).

METHODS

Standard conditions are important for image collection, and areas that show asymmetrical thermal patterns should be palpated to determine if pain is present and a detailed history of the local area and potential injury and/or irritation documented (Holst, 2000). This ongoing study was approved by the Human Subjects Research Committee of Mesa State College under exemption 45 CFR 46, analysis of archived data.

Equipment: The thermal camera is a Raytheon 250D with a 77mm lens (Raytheon Inc. Waltham, MA USA). The camera is an un-cooled ferroelectric-type and sensitive to the infrared spectrum from 7 to 14 µm. The camera provides video output in NTSC format with a resolution of 320 x 240 pixels grayscale, and is mounted on a tripod approximately 5 meters from the subject. The camera is then manually adjusted for focus, gain, and contrast levels to obtain the clearest image of the tissue area of interest.

The room is maintained at a comfortable temperature of approximately 20° C varying less than 1° C throughout the imaging process. Images are captured via digital video recorder and archived for further analysis and comparison. Images are collected for a minimum of 10 s per area of interest. Computer analysis and viewing is performed on the resulting digital video recording.

Procedures: An athlete presents for screening and/or injury evaluation in the imaging area for approximately 15 min prior to imaging. The athletes are dressed in shorts or shorts and sports bra. The 15 min pre-imaging period provides thermal acclimation to surroundings. Pressure on tissue areas of interest is avoided by remaining standing or seated based on whether the soles of the feet are of interest. Following the acclimation period, the athlete is placed in position for imaging and the athlete’s area(s) of interest are captured and stored as digital video. Each area that shows a thermal asymmetry is also palpated to determine the presence and extent of pain. In addition, any history of injury or irritation of the tissue area is documented.

Following imaging and recording, a report and a copy of the images are provided to medical personnel and the subject. Areas of pain and inflammation are noted along with ratings of pain.

Analysis: Analysis is based on visual inspection, palpation, and training and/or injury history. The camera is set so that whiter images are warmer than darker images. Areas of thermal asymmetry are palpated, recorded, and documented. This presentation shows four thermographic images of athletes with thermal asymmetries and areas of obvious inflammation.

RESULTS

Figures 1 through 4 show athletes with thermal irregularities. In three of the cases the athletes reported pain on palpation of the hotter area (Figures 1-3). In the fourth case (Figure 4), the athlete's initial imaging was secondary to complaints of an inability to dorsiflex the foot when fatigued. The imaging then led to surface electromyography showing bilateral asymmetries of peroneal muscle activation and finally to a nerve conduction velocity test that showed a malfunctioning peroneal nerve. The fourth athlete underwent surgery to relieve nerve entrapment and following this returned to full function. In all cases, the athletes were referred to the laboratory for thermal imaging, and then athletes were sent back to their physicians for further follow-up on their conditions.

Figure 1. *Male athlete with lower back pain. Note the warmer (lighter) area on the right side of his lumbar spine and sacrum*

Figure 2. *Female athlete with dramatically inflamed areas bilaterally and superior to her sacroiliac joints.*

Figure 3. *Female athlete with an area of knee pain.*

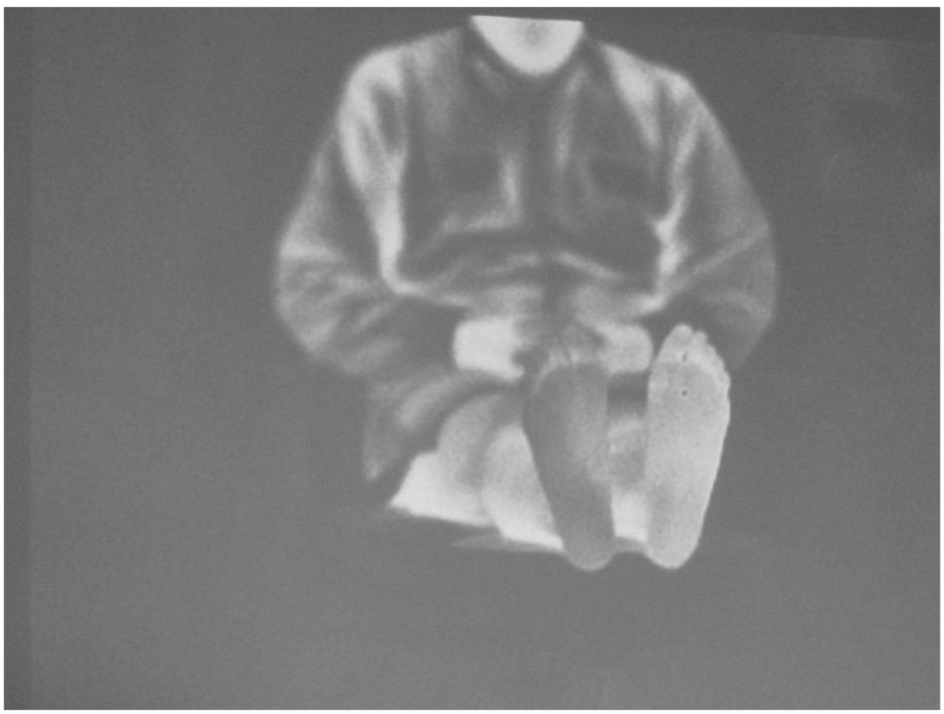

Figure 4. *Athlete showing a cold (darker) right foot. The colder foot was later shown to be caused by a nerve entrapment.*

DICSUSION

In all cases shown above, the athletes suffered for months before seeking medical help. For example, the fourth athlete case suffered from the condition despite typical therapies for over a year prior to being referred to the laboratory for thermography. The thermography check indicated that she was not malingering (Rotella, Ogilvie & Perrin, 1993; Mendelson & Mendelson, 2004) and that the thermal asymmetry was dramatic enough to merit further medical investigation. Previous efforts such as x-ray and magnetic resonance imaging of the foot and lower shank had resulted in no diagnosis. These diagnostic imaging techniques were concentrating on the athlete's foot and lower shank thereby missing the cyst lying more superior. The thermography, while not definitive, was the tipping point for further investigations and this ultimately led to resolution of her problem.

Modern literature has continued to reflect a relatively scant use of thermography in the detection and screening of injury in sport, particularly gymnastics, while thermography remains one of the least expensive utterly non-invasive methods of gaining insight into pain (Goodman et al., 1985; Gratt, Sickles & Wexler, 1993; Gratt, Sickles, Ross, Wexler & Gornbein, 1994; Graff-Radford, Ketelaer & Solberg, 1995; Huygen, Niehof, Klein & Zijlstra, 2004; Di Benedetto, Huston, Sharp & Jones, 1996; Friedman, 1994; Park, Hyun & Seo, 2007), reflex sympathetic dystrophy (Ben-Eliyahu, 1992; Friedman, 1994; Aybar, 1993; Jones, Ring & Clark, 1988; Karstetter & Sherman, 1991; Bruehl, Lubenow, Nath & Ivankovich, 1996; Sherman, Karstetter, Damiano & Evans, 1994), and complex regional pain syndromes (Niehof, Huygen, Stronks, Klein & Zilstra, 2007; Niehof, Huygen, van der Weerd, Westra & Zijlstra, 2006; Di Benedetto et al., 1996; Friedman, 1994; Awerbuch, 1991). Themography in sport has continued with studies involving stress fractures (Goodman et al., 1985; Devereaux, Parr, Lachmann, Page-Thomas & Hazleman, 1984)and arthritic and impingement conditions (Paterson et al., 1978; Denoble, Hall, Pieper & Kraus, 2010; Park et al., 2007).

Gymnastics training involves a great deal of exposure to potential injury (Sands, 2000). Moreover, gymnasts are seldom closely involved with a medical facility and very few programs employ certified athletic trainers and/or licensed physical therapists. As such, the use of an early warning system could decrease the severity and duration of injuries simply by alerting medical personnel and coaches to the potential for an injury due to hyper- or hypothermia detected via a thermal camera. Early intervention in medical issues is often cited as one of the primary methods to maintaining health and performance. Moreover, a coach can be more confident in making training load reductions when evidence is available that the athlete is showing early overuse symptoms.

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