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The Effects of Indoor Versus Outdoor Thermal Biofeedback Training In Cold-Weather Sports

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This field study examined the effects of indoor versus outdoor thermal biofeedback training on digital skin temperature for outdoor sports, and also tested the accuracy of estimating one's skin temperature in an outdoor environment. A sample of 25 university student volunteers (14 males and 11 females) were randomly distributed across three groups. Indoor subjects practiced exclusively indoors and outdoor subjects practiced exclusively outdoors, while control subjects did not receive any training. All pre- and posttests for all groups were conducted outdoors in an unheated tent. Subjects were trained twice a week for 4 weeks, with twice-a-day respective indoor or outdoor home practice on nontraining days. Results indicated the post-peroid change scores of the outdoor trained group to be superior to indoor trained subjects and controls when all groups were asked to perform outdoors. Indoor subjects were only able to maintain their temperature outdoors, whereas control subjects continued to lose temperature as they did during the pretest. Interestingly, there was no significant overall temperature difference between groups, and all subjects overestimated their temperatures regardless of training. Learning to control extremity temperatures in cold environments may depend on environmental context.

Physiological self-regulation via relaxation exercises and/or biofeedback training has increasingly become a popular method of mental and physical conditioning in a variety of sports. Some of the many sports in which auto-regulatory techniques have been found useful are riflery (Daniels & Landers, 1981), karate (Weinberg, Seabourne, & Jackson, 1981), scuba diving (Griffiths, Steel, Vaccaro, & Karpman, 1981), swimming (Doskin, Lavrentieva, & Gorsky, 1982), sailing (Franke, 1982), and generally for improving competitive performance (Machac & Machacova, 1980).

One physiological modality often employed in relaxation exercises and biofeedback is the calculation of hand temperature as an indicator of the relaxation response. Increases in the temperature of the extremities are typically associated with a calm and relaxed state whereas decreases in temperature commonly reflect increases in tension and anxi-

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ety. Resting palm and finger temperatures have successfully been shown to distinguish between anxious patients and nonanxious control patients in a hospital sample (Perera, Pinto, & Kay, 1984).

Learning to control peripheral skin temperatures has been studied extensively through thermal biofeedback training. Thermal biofeedback is a technique for teaching individuals to consciously and voluntarily change surface skin temperature without medication or external heat application. There are several clinical reasons why this particular technique may be relevant. For instance, self-regulation of peripheral temperatures by Raynaud patients has been shown to be specifically beneficial since their extremity temperature control is often irregular or nonexistent (Keefe, Surwit, & Pilon, 1980; Surwit, Bradner, Fenton, & Pilon, 1978). Individuals with migraine headaches also have shown improvements after learning to relax by increasing their temperatures via thermal biofeedback (Blanchard, Theobold, Williamson, Silver, & Brown, 1978; Mullinex, Norton, Hack, & Fishman, 1979). It seems plausible that thermal biofeedback training for self-regulation of extremities may also have practical application in cold weather sports such as skiing, hockey, football, and mountaineering. Certainly this training might increase overall performance and concentration as a result of relaxation; moreover, it may also provide some protection against cold injuries such as frostnip or frostbite (Kappes & Mills, 1982; Taub, 1977).

Many of the studies on digital skin temperature (DST) self-regulation under cold stress have trained subjects in warm environments, and then tested their ability to self-regulate DST under laboratory cold pressor tests in which only the hands were exposed (Donald & Hovmand, 1981; Keefe et al., 1980; Simkins & Funk, 1979; Stoffer, Jensen, & Nesset, 1977; Surwit et al. 1978). These studies suggest that transfer effects from training at room temperature to exhibiting the response under cold stress is minimal at best. However, recent studies have trained and tested subjects on their thermoregulatory abilities inside controlled temperature chambers with total body exposure (Chapman & Kappes, 1983; Hayduk, 1980, 1982; Zeiner & Pollak, 1980).

The results of these studies differ from the artificial laboratory cold pressor studies in that chamber studies report greater success with total body exposure. In fact, the chamber studies claim that thermal biofeedback training enables one to protect hands from excessive heat loss, feel less pain, and frequently exhibit greater manual dexterity when performing in cold or mildly cold environments. Ultimately, it seems quite reasonable that testing and training should most likely be accomplished in the setting for which the temperature skill would be performed.

The present field study was designed to answer two major questions. First, what are the effects of indoor versus outdoor thermal biofeedback training on digital skin temperature when demonstrating self-regulation in a mildly cold outdoor environment? Second, how accurately can one estimate his or her skin temperature in a mildly cold environment as a result of training? This second question becomes quite important when one considers that many cold injuries such as frostbite occur frequently without any knowlege of when the skin has started to freeze.

Method

Subjects

The initial sample of 30 university student volunteers enrolled in mountaineering, arctic survival, and psychology classes agreed to participate in what was announced as a study on frostbite prevention. The initial randomly distributed sample contained 10 subjects per group. Early in the study, however, four subjects withdrew from the outdoor group, one subject withdrew from the indoor group, and one outdoor subject agreed to become an extra control. The change in subject number reflected individual schedule changes and specific personal decisions rather than any known systematic bias or trend. The final sample contained 14 males and 11 females, with 5 subjects training outdoors, 9 subjects training indoors, and 11 control subjects. The age range was 19 to 40 years and the mean was 26 years.

Apparatus

During baseline and experimental sessions, DST was measured by a Digitec thermometer (Model No. 5820), with three Yellow Springs thermistors for skin, outdoor, and tent temperatures. Subjects practiced with auditory and visual feedback on a Cyborg P642 thermal trainer during training sessions. This monitor displays the actual temperature value to a 100th of a degree, and a light dot beeps simultaneously with each 100th of a degree increase. Each subject used a BF-110 Electro-therm trainer for home practice. A Northface Pole-sleeve, 3-man arctic tent was used for all baseline testing and training of the outdoor group.

Procedure

Each subject was asked to refrain from eating, drinking, or exercising 1 hour prior to his or her baseline appointments. All subjects participated in three pretest baseline measurements, which consisted of a 20-minute session every other day across 1 week. Identical measurements were taken 4 weeks later during the posttest. During baseline sessions subjects were asked to sit inside a tent while the experimenter recorded their DST from the middle finger of their dominant hand. The experimenter and the thermal monitor were located behind the subject in the tent. The tent door remained open during testing and basically provided shelter during occasional snow and rain. In- and out-of-tent temperatures were recorded at the beginning and end of every session. Subjects were asked to think warm relaxing thoughts and not to place their hands toward their body or make any unnecessary movements. An Autogenic Relaxation tape was played during the 15-minute training period (Schultz & Luthe, 1969). Subjects were seated on a thermal pad, with both hands on their knees and palms facing upward.

Two experimenters collected all the data by alternating training and baseline sessions across all subjects. Training sessions consisted of a 5-minute rest period followed by 15 minutes of thermal biofeedback. DST scores were recorded every minute. Subjects were also asked to estimate their temperatures during pre- and postbaselines at the end of each session and these estimates were subtracted from their actual temperatures to serve as an accuracy score. Indoor subjects practiced exclusively indoors and outdoor subjects practiced exclusively outdoors, while control subjects did not receive any training.

All pre- and posttesting for all groups was conducted outdoors in the tent. Both indoor and outdoor training groups received a total of eight experimental sessions of thermal biofeedback and 40 home practice sessions. Subjects were trained twice a week for 4 weeks, with twice-a-day respective indoor and outdoor home practice on nontraining days. Subjects presented 3 $\times$ 5 cards with dates and times of scheduled home practice. The three pre- and three postbaseline sessions were averaged to constitute a mean pre- and a mean post- DST measure. In all, 25 subjects times three preassessment and three

Table 1

Overall Pre/Post Test DST Means and Standard Deviations by Group

Test	Indoor *n*	*M*	*SD*	Outdoor *n*	*M*	*SD*	Control *n*	*M*	*SD*
Pre	5	73.24	14.24	9	72.61	13.93	11	70.14	11.88
Post	5	79.36	11.89	9	79.18	9.79	11	73.83	8.19

Note. All temperatures are in°F.
Celcius = (Fahrenheit −32) × .5556.

postassessment sessions, plus 25 subjects times eight training sessions resulted in 350 individual appointments necessary to complete this study.

Results

Because surrounding air currents and ambient temperature may influence skin temperature, tent temperature was selected as a covariate. Separate analyses of covariance were performed on the averages of the 15-minute pre/post baseline temperatures across groups, with in (M = 52° F) and out (M = 45° F) tent temperatures serving as covariates. The tent temperature covariates were averages of the three pre- and three postvalues obtained during each testing session. Both pre/post DST averages were not statistically significant, F (2, 24) = .09, $p > .10$, F (2, 24) = .77, $p > .10$ (see Table 1).

Another ANCOVA analyzed change scores from base on pre- and posttests. Overall pretest change scores were not significant, F(2, 24) = 1.05, $p > .10$, thereby indicating the effectiveness of random assignment across groups (see Figure 1). However, overall

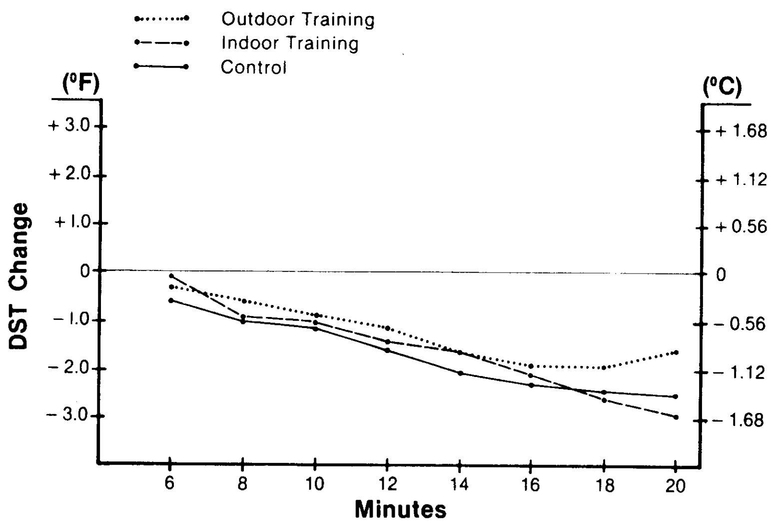

Figure 1 — Mean pretest digital skin temperature changes over time.

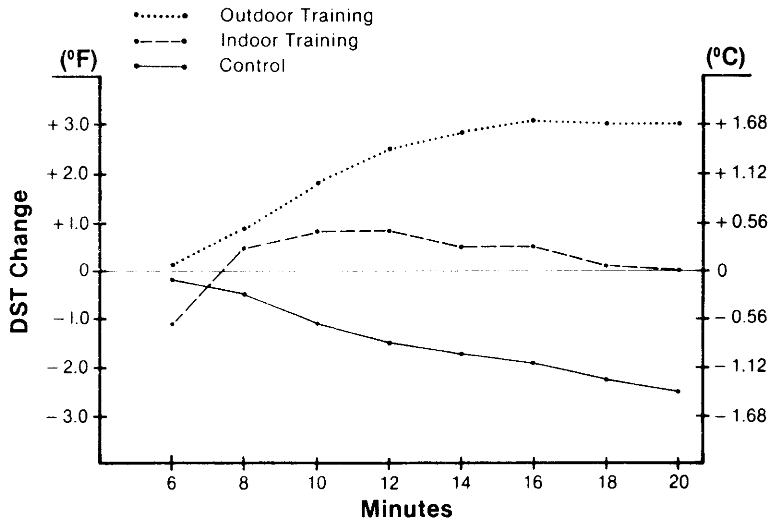

Figure 2 — Mean posttest digital skin temperature changes over time.

posttest change scores over time indicated significant differences across groups, $F(2, 24) = 5.25, p < .01$ (see Figure 2). On the average, outdoor subjects increased their temperature ($M = +3.04°$ F) and indoor subjects maintained their temperature ($M = +0.04°$ F), while controls decreased their temperature ($M = -2.59°$ F) when measured outdoors.

Finally, accuracy in estimation was not statistically significant across groups for pretest, $F(2, 24) = .05, p > .10$ or posttest, $F(2, 24) = .40, p > .10$. All subjects were found to overestimate their actual pre- and posttemperatures: outdoors (7.4° F), indoors (7.2° F), and controls (6.9° F).

Discussion

Outdoor skin temperature increases were found to be superior in subjects trained outdoors as compared to indoor subjects when performing outdoors. Unfortunately, since all groups were not compared for indoor performance, it is difficult to predict if outdoor performance would transfer indoors. Certainly indoor subjects produced the highest training temperatures while practicing indoors (96.5° F). However, indoor subjects were only able to maintain their temperatures outdoors while control subjects continued to lose temperature just as they did during the pretesting. The transfer value of the training for those trained outdoors seemed to be responsible. Specifically, the transfer of a response is likely related to the similarity of the conditions evoking such response. Success may depend on environmental context. Thermal biofeedback training in hockey, for example, might be better accomplished on the ice rather than in a warm gymnasium or locker room.

Because the measurements in the present study were made in a resting state, it is still questionable if handwarming resulting in relaxation would be useful when actively engaged in competition. Some athletes have claimed it is impossible to relax and remain actively engaged in competition. Other athletes claim just the opposite and believe the key to successful competition in any sport is the ability to relax and concentrate. The question of being "up" or motivated has long been established by the traditional inverted-U performance curve. Simply stated, drive or motivation is necessary to a point of optimal performance, beyond which performance begins to deteriorate—hence the law of diminishing returns. Maintaining the appropriate balance is perhaps a desirable skill before and/or during competition. Thermal biofeedback training aimed at teaching relaxation and specific handwarming may be feasibly applied in skiing while waiting for a run, or possibly in football when on the sidelines waiting to play. Further studies may need to examine the actual performance scores of athletes trained in biofeedback versus no biofeedback training, or training in other self-regulating techniques.

Interestingly enough, all groups overestimated their hand temperature values regardless of training. All groups believed their temperatures were 7° F higher than actually observed. While it seems reasonable to expect this response from subjects with no outdoor training experience, it is quite surprising that outdoor subjects were also unable to make accurate estimates as well. Subjects trained outdoors were able to demonstrate increases, but without recognizing their actual temperature values. This may suggest "conditioning without awareness" or conditioning without having the discriminatory knowledge of their own temperature response. In the present study, however, subjects were not trained on this specific skill (temperature estimation), but were simply trained to increase temperatures by relaxing. Therefore, it may be that these subjects only learned what they were taught, namely to produce skin temperature increases outdoors. Had we asked subjects to report subjective increases and decreases, perhaps trained subjects would have been quite accurate in their discrimination. In the present study, thermal biofeedback training alone, without specific estimate discrimination training, did not allow subjects to develop accurate estimation of their actual skin temperature at rest.

Because of the risk of possible cold injury in some outdoor sports, knowledge of one's current hand or foot temperature may prove to be a good health practice as well as perhaps providing a competitive edge. Biofeedback research for cold-weather sports (i.e., mountaineering or skiing) may need to be specifically adapted for accuracy in hand temperature recognition, rather than only teaching handwarming as part of the relaxation response.

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