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Comparison of the physiological and psychological benefits of tree and tower climbing

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Abstract

Considerable empirical and theoretical research asserts that nature and outdoor activities have restorative and therapeutic benefits. Research into the effects of environmental therapy on human behavior indicates that interaction with natural surroundings enhances well-being and encourages better health. We compared the physiological and psychological effects of climbing a live tree in a forest with those found after climbing a concrete tower of the same height in the same forest. Physiological and psychological tests were conducted on the climbers before, during, and after each climb. Physiological test results indicated that climbers' bodies were more relaxed after tree climbing than after tower climbing. Psychological results indicated greater vitality, and reduced tension, confusion, and fatigue while tree climbing, when compared to tower climbing.

Keywords: Cortisol; Environmental therapy; Heart rate; Parasympathetic nervous system; POMS; Tree climbing

Introduction

Recreational tree climbing has been gaining popularity as a form of organized outdoor activity. In April 2000, Tree Climbing Japan (TCJ, a nonprofit organization) established the first tree-climbing school in Japan. Although TCJ organizes recreational tree-climbing activities, the organization's main focus is the creation of tree-climbing programs that enhance the therapeutic and rehabilitative aspects of climbing trees. Programs were created for tree and forest appreciation, preservation, and environmental education. Tree-climbing-based rehabilitation (TreeHab) and tree-assisted-therapy (Tree Therapy) programs were also established to enable disabled persons and people of all ages to climb trees. (TreeHab and Tree Therapy are original program names and registered trademarks of TCJ.)

In July 2001, as part of the TCJ TreeHab program, Toshiko Hikosaka (57 years of age) became the first paraplegic person in the world to leave her electric wheelchair and climb to the top of a 78-m-tall Sequoia tree. Mass media coverage of this event created immense public interest in TCJ TreeHab and Tree Therapy programs throughout Japan.

Between 2000 and 2005, over 26,000 people of varying ages and abilities have participated in TCJ tree-climbing activities across Japan. However, there appear to be no scientific studies or empirical data that might explain the popularity of these tree-climbing programs, or establish whether there are any psychological or physiological therapeutic benefits to be gained from recreational tree climbing. The current research sought to address these issues.

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As an initial step, we conducted personal interviews and collected questionnaire-based data from 600 participants. When asked, "Why do you like tree climbing?" a large proportion of the participants reported a belief that tree climbing had both psychological and physiological benefits, enhanced their awareness of environmental concerns, and inspired them to participate in forest rejuvenation projects. Both able-bodied and disabled people reported that after climbing a tree they experienced less pain and fatigue, along with greater vitality and clarity of mind, increased self-worth, and an increased desire to help trees and the environment.

To investigate these therapeutic claims, it was important to consider other variables in the tree-climbing experience that might contribute to the perceived therapeutic benefits, such as the natural environment and the experience of being outdoors. Previous research shows a direct correlation between natural surroundings and restorative and stress-reducing effects (see Hartig et al., 2003; Kaplan and Kaplan, 1989; Parsons et al., 1998; Ulrich, 1981, 1984; Ulrich et al., 1991). Hartig et al. (2003) compared walking in an urban environment to walking in a nature reserve and showed that positive effects had increased and anger had decreased by the end of the walk in the nature reserve, while the opposite pattern emerged in the urban environment. Ulrich (1983) proposed that humans are biologically prepared to respond positively to certain environmental features and that evolution predisposes us to have a restorative response to certain natural scenes. Ulrich (1983) further proposed that viewing a scene with natural content such as vegetation or water can evoke positive emotions, support nonvigilant attention, restrict negative thoughts, and aid in a return of autonomic arousal to more moderate levels. Ulrich's (1984) research, which indicates that the view through a window could positively influence recovery from surgery, suggests that views of outdoor surroundings and nature might also have rehabilitative effects for tree climbers. A large majority of the tree-climbing participants questioned were from large urban centers and the possibility needed to be addressed that relief from work pressures and urban stressors through outdoor recreation, as documented by Knopf (1983) and Schreyer (1986), was responsible for their positive experience of tree climbing. If the experience of being in natural surroundings was primarily responsible for any positive physiological or psychological effects found among tree climbers, a similar effect should also be achieved by performing an activity other than tree climbing in the same forest environment.

Another theory that would correlate with the tree climbers' experiences could be attention restoration theory (ART; Kaplan, 1995; Kaplan and Kaplan, 1989). According to the ART theory, humans have a need for a restoration from attention fatigue and this is possible through psychological distance from routine mental contents (or being away) coupled with effortless, interest-driven attention (fascination) sustained in orderly environments of substantial scope (extent) as well as an environment that matches the person's inclinations and the demands imposed by the environment for the intended activities (compatibility). Kaplan and Kaplan (1989) believe that these four factors are often found in high levels in natural environments. This is particularly true for tree-climbing activities. Participants are (being away) from urban centers, (fascinated) by technical techniques to safely climb a big tree, (intent) on the task of ascending to the top of a tree, and finally taught the techniques to make them (compatible) to the task of safely climbing the large tree, thus possibly explaining those claims of less fatigue. However, using the (ART) model on a different recreational activity in the same surrounding as tree climbing should in theory produce similar effects.

While tree climbing may have similarities with other outdoor recreational activities, it is unique in providing the opportunity to have body contact with a live tree. Tree climbing offers participants the opportunity to discover a live tree and feel part of the living natural environment through an intimacy and interaction with a living tree. However, it is possible that neither the act of climbing a tree nor intimacy with a living tree produces any resulting therapeutic benefits but that such benefits arise from the thrill of being elevated above the forest floor and the resulting view that this provides.

Laboratory tests on natural stimuli indicate that heart rate (HR) responses are different when subjects are viewing urban and natural environments (Laumann et al., 2003). Laumann et al. (2003) found that subjects who watched videos depicting a natural environment had a significantly longer interbeat interval (IBI) or lower HR than subjects who watched videos of an urban environment. In the light of these well-documented benefits of the natural environment itself, we sought to determinate the validity of claims that specific therapeutic benefits result from the act of tree climbing by performing a task-specific comparison.

It is widely accepted that mental and emotional activity can alter the activity of the autonomic nervous system (ANS). Parsons et al. (1998) showed that activities such as driving through nature-dominated roadside environments decreased the magnitude of the autonomic response to a stressor and that artifact-dominated roadside environments both slowed down autonomic response and impeded recovery from stress relative to exposure to nature-dominated roadsides, indicating that our ANS is affected by interactions with the natural environment. With this research in mind, we hypothesized that climbing a live tree would produce different psychological and physiological effects in climbers than climbing an artificial tower of equivalent height situated in the same forest environment.

Methods

Subjects and location

In recruiting subjects, we attempted to represent as closely as possible the profile of an actual tree-climbing population, as logged by TCJ on insurance forms completed prior to each climb. Records of 734 adult tree climbers who climbed in the Seto area community forest from April 2003 to April 2004 showed a mean age of 27.3 years and a female to male gender split of 32.9%. We recruited a subject group of 11 inexperienced climbers with an age range of 22–51 years (mean = 25.7 years) from university students and faculty members. The gender split was four females and seven males, approximating that of actual tree-climbing participants. To ensure that each member had equal knowledge and experience of tree climbing, the entire group underwent a 4-day tree-climbing course. All subjects were taught the double rope technique (DRT), the method used by TCJ for tree-climbing programs.

To minimize daily variations in weather, data collection was limited to a single day. To further minimize weather variations within the day, we limited our data collection to the time when temperature, humidity, and light would be most constant, i.e., late morning until mid-afternoon. Within this time frame, it was necessary to allow the subjects a rest period between climbing the tree and the tower, as well as regular rests within each climb. As rushing the climbers could have been dangerous and would not have been conducive to an investigation into the therapeutic benefits of tree climbing, it was only possible to use a small subject group for this experiment.

The experiment was conducted in the location used by the 734 adult tree climbers that the subject group was modeled on, both to represent the real climbing population and because a large concrete tower was present within the same forest (Fig. 1). The height to which the participants climbed was set at 9 m and an artificial round wooden branch (15 cm in diameter) was attached to the concrete tower at this height (Fig. 2). Fig. 3 shows the subject group sitting on the artificial branch. Trees with branches of a similar diameter, located at approximately the same height (9 m), were then selected for climbing (Fig. 4). Particular care was taken to ensure that all ropes, harnesses and rigging for the tower and tree climbing were identical in both climbing scenarios.

While performing four training climbs and three additional experimental climbs we established that the subject group found 8–10 m to be a comfortable height, which also provided an excellent view of the surrounding forest. Although we used a small sample group, the various practice tests indicated that varying the order between tree climbing and tower climbing did not produce any noticeable difference in data.

Fig. 1. View of tower, Seto forest.

Fig. 2. View from the tower artificial branch at 9 m height, Seto forest.

Fig. 3. Artificial wooden branch at 9 m height tower.

Fig. 4. Tree climbing, 9 m. Seto forest.

Physiological measurements

The act of climbing in an outdoor environment made physiological and psychological data collection and measurement particularly challenging. Unlike laboratory research, any equipment we used needed to be light and mobile; it could not restrict or hamper freedom of movement during climbing, nor could rigorous movement affect the accuracy of the measurements. Our desire to collect as much reliable physiological data as possible was hindered by the practicality of the equipment. For example, our early experiments used an electroencephalogram to measure CNS activity (brain waves), but the head gear, with all its electrodes and wires, was too irritating and restrictive for the climbers and slight movements affected accuracy of the measurements, making the equipment incompatible with the task.

To assess the activity of the ANS during tree and tower climbing, we measured the IBI and HR using a HR monitor (Polar S810I; Polar Electro Oy, Kempele, Finland) attached to the chest and wrist of each climber. This instrument was not restrictive or sensitive to movement, and was light and easy to attach to the subjects. To create a stress baseline we used a mathematical stress test, the Uchida–Kraepelin test. This test, which was developed by Yuzaburo Uchida based on the work of Kraepelin, is used extensively in Japan to determine a stress baseline for a variety of physiological tests, and is administered to over a million people annually. The method involves using mathematical addition questions under a time stress situation in which subjects are required to answer each line of addition in less than 1 min consecutively over 10 min.

We analyzed the IBIs using spectrum analysis with the fast Fourier transform method. Using coarse graining spectral analysis, we separated fractal and harmonic components (Yamamoto and Richard, 1991). To estimate the activity of the ANS, we calculated an integral power spectrum from 0.04 to 0.15 Hz for the low frequency (LF), and from 0.15 to 0.5 Hz for the high frequency (HF). To calculate the activity of the parasympathetic nervous system (PNS), we calculated the proportion of HF over the total power spectrum (HF/TPS). We determined the ratio of activity of the ANS to that of the PNS as LF/HF (Hayano et al., 1990, 1991).

Since the early studies of Mason (1968), activation of the hypothalamic–pituitary–adrenal (HPA) axis and the subsequent release of cortisol has been considered one of the major components of physiological stress response in humans (Ockenfels et al., 1995). Cortisol concentrations in saliva correlate positively with stress (Makara et al., 1980) and individuals with higher levels of psychological well-being have markedly lower levels of cortisol (Lindfors and Lundberg, 2002). Given the capacity to collect samples independent of laboratory or medical personnel at any desired frequency (Kirschbaum and Hellhammer, 1994), measuring saliva cortisol content appeared suitable for our experimental design. However, cortisol saliva content measurement does pose some limitations, e.g., when it can most accurately be measured and interindividual variations in personal cortisol content. Subjects must also be subject to dietary restrictions. To measure the concentration of cortisol in the subject group's saliva, we used an enzyme-linked immunosorbent assay (ELISA kit mg/ml; Neogen Corp., Lansing, MI, USA). Saliva was collected by saturating a cotton swab within the buccal cavity before, during, and after each climb. The concentration of cortisol is easily affected by the intake of caffeine or alcohol taken prior to the tests. It was necessary that the subjects did not consume either of these substances for at least 12 h before the tests. To limit the potentially confounding effects that variations in diet among different subjects might have had on salivary cortisol concentrations, all participants agreed to avoid caffeine and alcohol the day before the climb and all ate a meal late in the morning prior to the experiment. Cortisol concentrations in human saliva are most constant from around noon till late afternoon, so we designed our experiment to accommodate this time window. The preparation and data collection for IBIs was monitored prior to, during, and after each climb. Cortisol swabs were self-administered under the direction of the monitoring team.

Psychological measurements

To determine the psychological state of mind of the participants, we used the Japanese version of the Personal Mood State Tests (POMS; McNair et al., 1992). POMS tests are intended to measure the "Right Now" types of mood states. The tests consist of 65 questions to identify six different mood states: tension–anxiety, depression, anger–hate, vitality, fatigue, and confusion. The subjects enter a numerical equivalent on a scale of 1–5 from "Definitely Negative to Definitely Positive." In addition, we administered a short questionnaire while the climber was at the prescribed height above the ground (9 m) either in the tree or on the tower.

Climbers also answered a short questionnaire as a self-evaluation of tree climbing and tower climbing. We did not ask them to compare, but to rate, each activity separately. The questionnaire consisted of six questions relating to the climbing experience. Was the climbing experience enjoyable? Did you feel a sense of accomplishment? Were you able to relax? Was the climb revitalizing? Were you frightened while climbing? Did you feel anxiety or stress while climbing? The questions were given a score (1–5) from "Definitely No" to "Definitely Yes." They were self-administered after both tree and tower climbing.

Statistical methods

All aforementioned physiological and psychological data were collected 20 min before each climb, after a rest period of 10 min on the tree/tower limbs during each climb, and 30 min after each climb, allowing the body and mind to adjust to each phase of activity. The practicalities of creating an experimental design, which enabled collection of psychological and physiological data on subjects in the same environment, under different conditions, required us to limit the subject group to 11 people. Although small control groups are sometimes used in physiological experiments, we recognize that for psychological studies the group size makes it difficult to state that our results are statistically valid. However, for the purpose of this research we used two-way analysis of variance (ANOVA) to compare data from these four different states. Statistical significance was accepted at $P<0.05$. Data are presented as means $\pm$SE. We used Fisher's test for multiple comparisons. Spearman's correlation matrix was used to calculate correlation coefficients.

Results

Interbeat interval

Fig. 5 shows the TPS for the combined LF and HF data when compared to the stress baseline. An increase in the TPS indicates that the ANS is active. The TPS was the same both before and after tree climbing, but there was a measurable increase in the TPS after the tower climbing, when compared to levels found beforehand. The TPS after tower climbing was also measurably higher than the TPS after tree climbing. Therefore, both the sympathetic nervous system (SNS) and the PNS were measurably more active after tower climbing than after tree climbing. There was an increase in PNS activity after tree climbing compared to during tree climbing (Fig. 6), which is considered to be an indication of increased relaxation or "Less Stress". No difference was found in the activity of the PNS during or after tower climbing. As shown in Fig. 7, there was a definite increase in the variance of LF/HF, which indicates that the SNS was more active than the PNS during tree climbing, whereas after tree climbing, the PNS was the more active system.

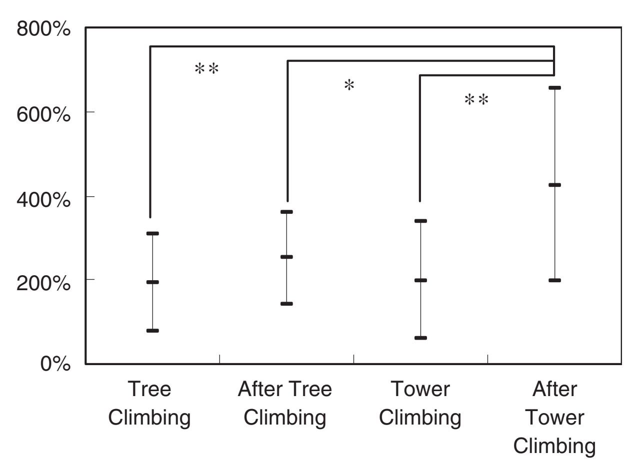

Fig. 5. Total power spectrum against stress base. $*p<0.05$, $**p<0.01$.

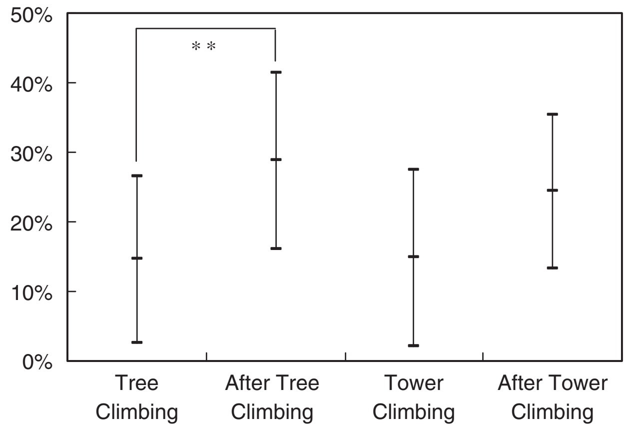

Fig. 6. Percentage of high frequency (HF) against total power spectrum (TPS) indicating parasympathetic nervous system (PNS).

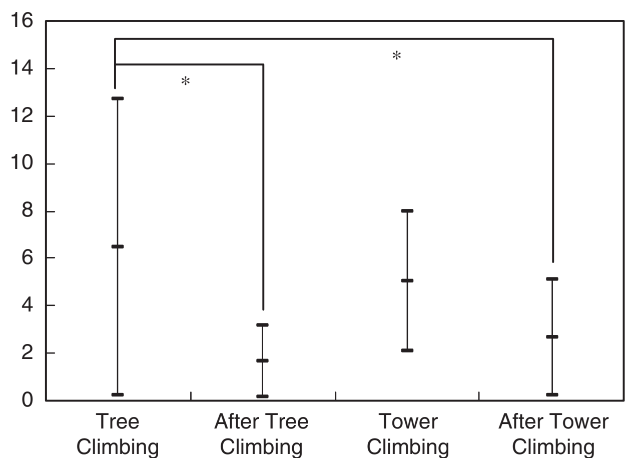

Fig. 7. LF/HF indicating PNS and sympathetic nervous system (SNS) activity.

The results set out in Figs. 5–7 suggest that climbers experienced a decrease in HF% while climbing a tree, and an increase in LF/HF that reflected activation of the SNS and TPS, which may have been associated with slight tension or nervousness. Following the tree climbing, HF increased while LF/HF decreased, which is indicative of PNS activity. At the same time, we also observed a slight increase in the TPS, which we interpreted as a state of slight relaxation.

Cortisol concentrations

We were unable to collect reliable data from two subjects; data presented are for the remaining nine subjects. We also had difficulty collecting proper data for our subject group while they performed their climbs. We suspect that the time period we allotted for resting on the tree and artificial branch was not adequate to allow the subjects' bodies to recover from the physical activity of climbing. When considering future research using cortisol concentration as a measurement, it would be advisable to lengthen the resting period to more than 20 min after strenuous exercise such as tree or tower climbing. Cortisol concentrations measured 30 min after tree and tower climbing were more reliable and indicated that five of our subject group had lower cortisol concentrations after tree climbing compared to tower climbing (Fig. 8). This suggests that they felt less stress after tree climbing compared to tower climbing. The remaining four subjects experienced higher levels of cortisol concentrations after tree climbing compared to tower climbing, indicating less stress after tower climbing. It is important to note that cortisol concentrations in humans are not constant. Cortisol concentration is higher in the morning, leveling off from noon to mid-afternoon and declining further thereafter. We designed our experiment to compensate for this natural decline by limiting our testing time frame for tree and tower climbing to within the most stable period. The final four subjects to climb the tower exhibited lower cortisol concentrations, suggesting the possibility that the later timing might have influenced the cortisol data measurements slightly in favor of the tower, in those subjects.

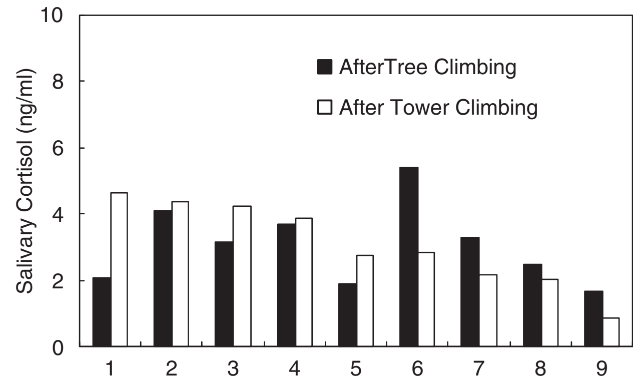

Fig. 8. Subject salivary cortisol.

Psychological effects of climbing

The results of POMS are presented in Figs. 9–12. Climbers experienced a significant increase in tension while climbing the tower compared to the tree, and there was a significant decrease in tension after climbing the tower (Fig. 9). Vitality was higher during the tree climb than during the tower climb, and there was significantly greater vitality after the tree climb than after the tower climb (Fig. 10). Fatigue experienced while tower climbing was significantly higher than that experienced while tree climbing (Fig. 11). Similarly, there was a

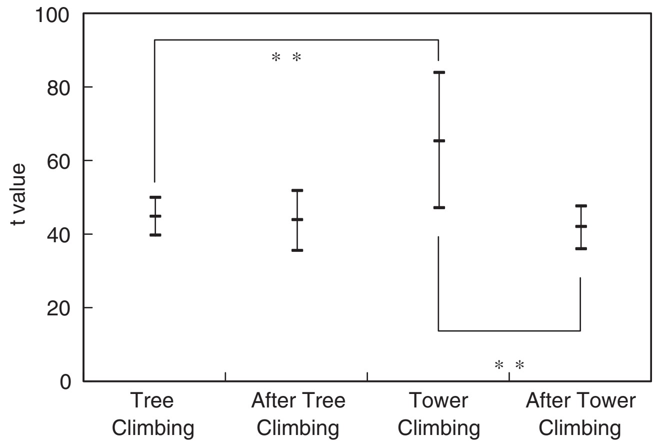

Fig. 9. Tension results, personal mood state tests (POMS).

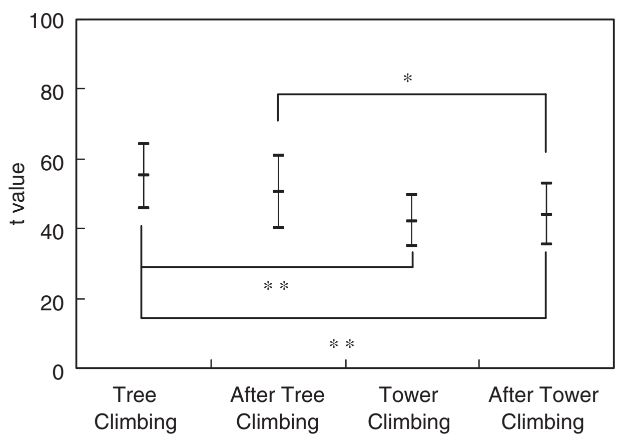

Fig. 10. Vitality results, POMS tests.

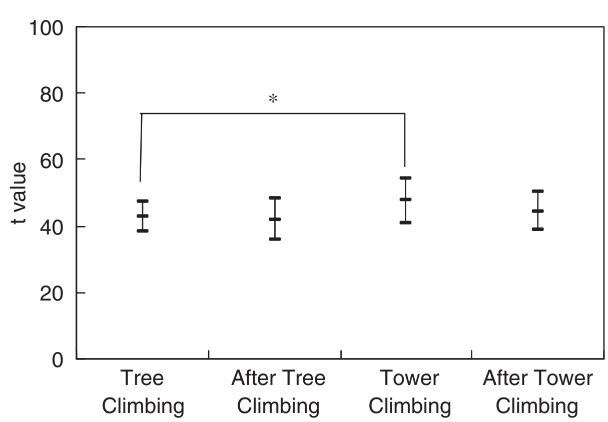

Fig. 11. Fatigue results, POMS tests.

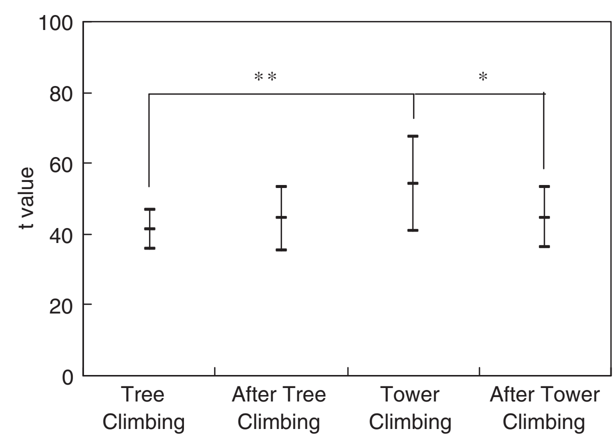

Fig. 12. Confusion results, POMS tests.

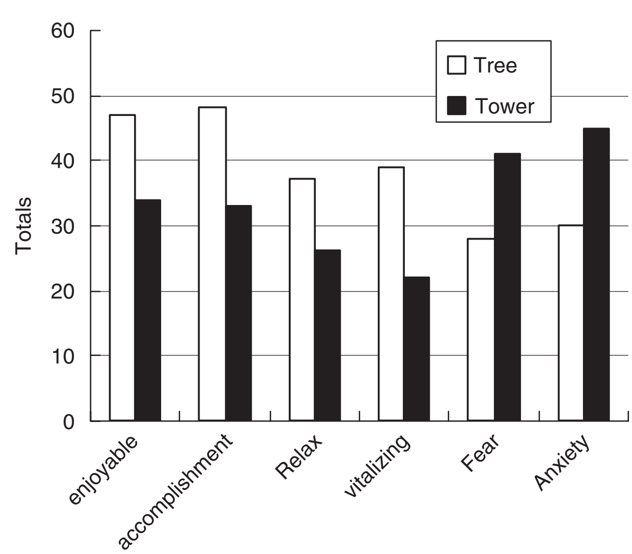

Fig. 13. Results of climbing questionnaire.

greater increase in confusion during tower climbing than during tree climbing; confusion was significantly greater during than after tower climbing, but no such difference was observed for tree climbing (Fig. 12).

The results of POMS suggest that more tension, confusion, and fatigue are experienced when climbing the tower than when climbing the tree. Moreover, there was an increase in vitality while tree climbing, whereas the opposite occurred while climbing the tower. Therefore, tree climbing was associated with positive emotions, whereas tower climbing was associated with negative emotions. The climbing evaluation questionnaires revealed similar findings. Fig. 13 gives the results of the total points for each of the climbing evaluation questions. Tree climbing was rated more highly in the positive aspects of climbing while tower climbing was rated more highly in the negative aspects of climbing. This trend was also evident in our other psychological tests.

Discussion

Both tree and tower climbing increased the TPS and the activity of the SNS; however, the activity of the PNS was elevated only after tree climbing and not after tower climbing. Generally speaking, increased PNS activity results in a reduction in nervous tension (Gaku et al., 1997). After climbing the tower, parasympathetic activity was not elevated substantially, and the TPS was greater, indicating that the climbers experienced an increase in nervous tension while climbing the tower. The psychological tests revealed an increase in vitality and a decrease in tension, confusion, and fatigue while climbing the tree compared to climbing the tower. The results of the questionnaire administered while subjects were 9 m above the ground were similar to the results of POMS tests. These results are consistent with the conclusion that tree climbing is associated with positive emotions (e.g., vitality), whereas tower climbing is associated with negative emotions (e.g., fear and anxiety). It is also important to note that the increased vitality and positive emotions that tree climbers experienced may have diminished confusion, tension, and fatigue, but may also have contributed to activation of the SNS. Upon returning to the ground after the exciting and rewarding experience of climbing, a feeling of relaxation and accomplishment would not be unexpected; this would reflect increased parasympathetic nervous activity.

Collectively, the results of our study suggest that the psychological and physiological benefits of tree climbing are greater than those of tower climbing. This is based on the fact that the results of the physiological and psychological tests were concordant. The psychological tests indicated that tree climbers experienced increased vitality and reduced confusion, tension, and fatigue; the physiological data (LF/HF, HF%, and TPS) indicated that tree climbing resulted in greater PNS activity. The lack of research in this area required us to create a pilot experiment to investigate the possibility that the act of tree climbing in itself could have psychological and physiological benefits to tree climbers. Notwithstanding the size of our subject group, this research supports our hypothesis that climbing a living tree and climbing an artificial tower have different effects on climbers. It also indicates that tree climbing does have distinct psychological and physiological benefits.

The research in this paper was intended to offer a new perspective to the studies of restorative experiences in natural environments and explore the therapeutic possibilities of tree climbing. Further research is needed in this area; using a larger subject group within the same time frame and environment could be made possible by building a number of towers to facilitate simultaneous climbs. Due to the individuality and restrictive time frame of cortisol content in salvia, additional methods of collecting physiological data in lieu of cortisol testing could be another consideration for future research. Based on our pilot experiment and the assumption that tree climbing does have psychological and physiological benefits to tree climbers, we intend to further investigate and explore the therapeutic benefits of tree climbing in conjunction with specially adapted tree-climbing programs that enhance these therapeutic and rehabilitative properties. Something of particular interest to us is further research into the benefits of the tree-climbing-based-rehabilitation program "TreeHab" and tree-assisted-therapy "Tree Therapy" programs for emotionally, physically, and mentally disabled people. For the purpose of our experiment, we limited our research to tree climbing in a community forest, but tree-climbing activities can also be performed in city parks and urban forests. In fact, just under half of TCJ climbing activities take place in city parks or urban surroundings. The implementation of special TreeHab programs in urban and community forests could not only create a new perspective on the restorative and therapeutic benefits of natural environments, but could create a new field of therapy within community and urban forests. The popularity of TreeHab and Tree Therapy programs could influence future designs in urban greening as communities and governments create parks and urban forests to better accommodate therapeutic and rehabilitative tree-climbing activities.

References

Gaku, H., Toshio, M., Teruo, K., Tohru, F., 1997. Caffeine enhances modulation of parasympathetic nerve activity in humans: quantification using power spectral analysis. Journal of Nutrition 127, 1422–1427.

Hartig, T., Evans, G.W., Jamer, L.D., Davis, D.S., Garling, T., 2003. Tracking restoration in natural and urban field settings. Journal of Environmental Psychology 23, 109–123.

Hayano, J., Sakakibara, Y., Yamada, M., 1990. Diurnal variations in vagal and sympathetic cardiac control. American Journal of Physiology 258, H642–H646.

Hayano, J., Sakakibara, Y., Yamada, M., 1991. Accuracy of assessment of cardiac vagal tone by heart rate variability in normal subjects. American Journal of Physiology 267, H33–H40.

Kaplan, S., 1995. The restorative benefits of nature: toward an integrative framework. Journal of Environmental Psychology 15, 169–182.

Kaplan, R., Kaplan, S., 1989. The Experience of Nature: A Psychological Perspective. Cambridge University Press, Cambridge.

Kirschbaum, C., Hellhammer, D.H., 1994. Salivary cortisol in psychoneuroendocrine research: recent developments and applications. Psychoneuroendocrinology 19, 313–333.

Knopf, R.C., 1983. Recreational needs and behavior in natural settings. In: Altman, I., Wohlwill, J.F. (Eds.), Behavior and the Natural Environment. Plenum, New York, pp. 205–240.

Laumann, K., Garling, T., Stormark, K.M., 2003. Selective attention and heart rate responses to natural and urban environments. Journal of Environmental Psychology 23, 125–134.

Lindfors, P., Lundberg, U., 2002. Is low cortisol release an indicator of positive health? Stress and Health 18, 153–160.

Makara, G.B., Palkovits, M., Szentagoithai, J., 1980. The endocrine hypothalamus and the hormonal response to stress. In: Selye, H. (Ed.), Selye's Guide to Stress Research, vol. 1. Van Nostrand Reinhold, New York, pp. 280–337.

Mason, J.W., 1968. A review of the psychoendocrine research on the pituitary–adrenal cortisol system. Psychosomatic Medicine 30, 576–607.

McNair, D.M., Lorr, M., Droppleman, L.F., 1992. Profile of Mood States. San Diego Educational and Industrial Testing Service, San Diego.

Ockenfels, M.C., Porter, L., Smyth, J., Kirschbaum, C., Hellhammer, D.H., Stone, A., 1995. Effect of chronic stress associated with unemployment on salivary cortisol: overall cortisol levels, diurnal rhythm and acute stress reactivity. Psychosomatic Medicine 57, 460–467.

Parsons, R., Tassinary, L.G., Ulrich, R.S., Hebl, M.R., Grossman-Alexander, M., 1998. The view from the road: implications for stress recovery and immunization. Journal of Environmental Psychology 18, 113–140.

Schreyer, R., 1986. Motivation for Participation in Outdoor Recreation and Barriers to that Participation – a Commentary on Salient Issues. The President's Commission on Americans Outdoors (Motivation Section. pp. 1–8). US Government Printing Office, Washington, DC.

Ulrich, R.S., 1981. Natural versus urban scenes: some psychophysiological effects. Environment and Behavior 13, 523–556.

Ulrich, R.S., 1983. Aesthetic and affective response to natural environment. In: Altman, I., Wohlwil, J.F. (Eds.), Behavior and the Natural Environment. Plenum Press, New York, pp. 85–125.

Ulrich, R.S., 1984. View through a window may influence recovery from surgery. Science 244, 420–421.

Ulrich, R.S., Simons, R.F., Losito, B.D., Fiorito, E., Miles, M.A., Zelson, M., 1991. Stress recovery during exposure to natural and urban environments. Journal of Environmental Psychology 11, 201–230.

Yamamoto, Y., Richard, L.H., 1991. Coarse-graining spectral analysis: new method for studying heart rate variability. Journal of Applied Physiology 71, 1143–1150.