Physical Properties of Cold and Its Exploitation in New Wellness Services

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Abstract

This paper discusses multidisciplinary research of new wellness services that are associated with cold conditions and human comfort. The results of the research can be exploited by health care as well as tourism industry. There has emerged a growing interest towards experiences in arctic conditions. Tourists, for example, are constantly looking for new spectacular experiences like spending a night in the arctic winter. Our research shows that, although cold is often associated with discomfort rather than comfort, it is possible to create pleasant and healthy experiences safely in cold conditions.

In our case study a multicultural group of tourists stayed in a snow castle hotel for one night. Our goal was to find out how the cold affects the recovery and relaxation of the human body. The assessment method based on an accurate analysis of the subject's heartbeat and it provided information on the autonomic nervous system function through heart rate variability. In addition, we describe laboratory tests to produce particular arctic conditions artificially to exploit cold in tourism experiences. The thermodynamics of the physical phenomena are clarified.

Introduction

Tourism is a dynamic and growing economical industry. According to the World Travel & Tourism Council (WTTC), tourism is the world's fastest growing industry (WTTC 2012). Tourism has the potential to bring positive economic impacts to the region. Finnish Lapland is a scarcely populated area in northern Scandinavia. Tourism is one of the most important and promising sources of revenue in many areas in Lapland. Tourism brings welfare to many areas in Lapland as the traditionally strong industries (for instance forest industry) are struggling. The direct economic impact of tourism in Lapland has been EUR 595 million and the tourism industry has created 5,000 jobs (Regional Council of Lapland 2007). In addition, the indirect revenue is noticeable (Satokangas 2013). However, in order to sustain and give welfare to the region, including in the future, the tourism industry and tourism companies need to continuously develop and innovate their offers and products to the markets.

This research has been conducted in two small towns called Kemi and Rovaniemi located in Finnish Lapland. In Kemi, there are approximately 25,000 inhabitants and the town has been historically one of the most important industrial towns in northern Finland. There are two internationally attractive tourism destinations in Kemi – the Snow castle and the Icebreaker Sampo. As background, in Kemi, there have been 75,000 registered overnight stays in the year 2010 and the goal is to triple that and the revenue from tourism by year 2020. (FCG Finnish Consulting Group 2011.) Direct revenue from tourism in 2012 was around 21 million euro (Satokangas 2014). According to the Kemi Tourism Masterplan, the development in tourism will rely on the existing attractions – Snow castle and Sampo Icebreaker. The Snow castle will be developed so that the season will be prolonged, and the aim is to sustain the current competitive situation against the other snow castles and snow structures in other areas. There are only a few companies in the region that offer program services so that entrepreneurship and new innovations in this field will be encouraged. (FCG Finnish Consulting Group 2011.) In our paper, we focus on new possible wellness services in snow castles or, more generally, in arctic tourism.

The present arctic tourism services are based not only on the extensive experience of previous innovations but also on the understanding of cold properties in connection with human physiology and psychology. Cold conditions are usually regarded as something that should be eliminated in order to avoid cold stress for the human body. Nevertheless, for a very long time it has been well known, at least in northern countries, that a short exposure to alternating heat and cold stress is an excellent way to produce wellness and pleasure. Controlled heat and cold stress stimulate the autonomic nervous defense mechanisms of the body including, among other things, the blood vessel muscles and hair muscles on the skin.

The most common and oldest concretization of the controlled heat stress method is undoubtedly sauna. Nowadays, there exists a wide spectrum of techniques of sauna. One example of new innovations in the current arctic services is a sauna that is totally made of snow. The temperature in a snow sauna is below zero when starting the sauna. (Fig. 1) The basic idea to produce controlled heat stress in a snow sauna is the same as in a traditional sauna; you pour water on the heated stones to get hot steam to flow onto your skin. Since the temperature of your skin is much lower than that of the steam, the water vapor of the steam condenses onto your skin forming small water droplets. The latent heat of condensation is conducted into the skin, which makes the skin sense the heat despite the temperature of the air in the sauna. The increased humidity due to the steam and condensed water on the skin also reduce perspiration thereby increasing the heat stress. In snow sauna, the hot sauna stove is isolated.

Figure 1. Traditional sauna in The Arctic SnowHotel in Rovaniemi

New ideas for using sauna in tourism services arise in how various cold conditions can be produced, perhaps indoors, artificially, regardless of the weather conditions outside. This kind of experimental study in our research is conducted in the Artic Power (AP) laboratory, which is a research, development, and testing center for cold and winter technology. It is located near Rovaniemi international airport and is part of Lapland University of Applied Sciences. In our paper, we consider this study on the basis of thermodynamics.

Sleep is one of the basic needs of human beings and it plays a key role in maintaining the functional capacity of the brain (Härmä and Sallinen 2006). For tourists too, it is important to be able to rest and sleep well. There might be some skeptics among tourists wondering how well a person can really sleep in cold conditions like in a snow castle. However, people fall asleep quicker in the cold than at room temperature. The temperature difference between the sleeping room and the distal parts of the limbs correlates with the speed of falling asleep. (Partonen 2012.) As we fall asleep, the temperature in the inner parts of our body decreases and the temperature of the skin and limbs increases (Rintamäki et al. 2005). In our case study, we examined the recovery and relaxation of the human body during an overnight stay in a room at the snow hotel of the Kemi Snow Castle.

New wellness services in arctic circumstances

Developing the attractions of Kemi is important not only for Kemi but new innovations can also benefit the tourism development of Finland and other arctic regions. Tourism products, including the Snowcastle, have to renew their offers every year. There are new snow castles and other constructions made of snow growing every year all over Lapland, Finland, and other arctic regions. Competition is also tough in this branch. Moreover, the number of tourists has not recently been growing in Kemi. The rest of Lapland has the same challenge. (FCG Finnish Consulting Group 2011.)

However, according to Kemi Tourism Masterplan, Snowcastle will be one of the most fascinating tourism attractions in Lapland and in Finland also in the future. The Snowcastle product will be developed and snow and ice will be used in more creative ways in product development. (FCG Finnish Consulting Group 2011.)

The idea is that the snow and ice theme could also be seen and felt in the summertime – there could be an icebar, sauna made of ice, or snowballs, mentioned in the Kemi Tourism Masterplan as well (FCG Finnish Consulting Group 2011). There is a clear need for new products and innovations.

Generally speaking, there are tens of snowhotels and restaurants born every winter in northern Finland. SnowCastle of Kemi is one of them and it is the most popular. For many years it has been the largest snow castle in the world. Every winter it is built with a different theme and architecture. In 1996, the first snow castle drew 300,000 visitors. The area covered by the castle has varied from 13,000 to over 20,000 square meters. The highest towers have been over 20 meters high, the longest walls over 1,000 meters, and the castle has had up to three stories. Every year there has been an ecumenical SnowChapel with 50–100 seats, where numerous weddings of couples have taken place. Every year there has also been a restaurant and a hotel. The hotel offers a choice of double rooms and a honeymoon suite, all of which are decorated by artists using local materials. There are approx. 50 beds in the snow hotel. The rooms are 3 meters tall and have a floor area of 9 m^2. The walls between the rooms are 60 cm thick and the walls between the rooms and the corridor are 1.5–2 meters thick. The temperature inside the hotel is –5°C regardless of the outside temperature. Hotel customers sleep on spring mattresses in arctic sleeping bags lined with fleece bed sheets. The recommended sleeping attire includes a knit cap, socks, and long underwear. (Visit Kemi 2013.)

More generally speaking, globally, there has emerged a growing interest toward experiences in Arctic conditions. Tourists are constantly looking for new spectacular experiences (Pine 2006) like spending a night in the Arctic winter. Traditional goods and services are no longer enough (Pine and Gilmore 1999), and no tourism related company can today afford to provide basic service activities and ignore its guests' experiences (Pine and Gilmore 2011). Arctic circumstances have the capacity to offer exciting opportunities for today's tourist (Ritchie and Hudson 2009). Tourists can experience something new in a cool Arctic environment. This creates new demands for product development in tourism. The Regional Council of Lapland has also announced that one of the main goals in tourism product development is to move from services to meaningful experiences (Luiro 2013).

There is not only one definition for tourism experiences. In tourism research, the assumption is that experience is positive, valuable experience for the person who is experiencing it. Experience is very subjective and personal by nature, and it has to touch the person. It should attract the senses, emotions, and brain and it should also be mentally motivating. Every experience is born in an interactive situation between the personnel of the company, the guest, and all the other guests, and it depends on the mental and physical state of mind of the individual. (Pine and Gilmore 2011.) Words connected to experiences are pleasure, stimulation, refreshing, connection with others, personal importance of the experience, happiness, spontaneity, challenges, adventure, knowledge, learning, individuality, multi-sensory, and story. These words may give guidelines to what experience in tourism means. There has been research with psychological, sociocultural, or economic perspectives to experiences (Lüthje and Tarssanen 2013). According to Pine and Gilmore, experiences are commercial, produced experiences. The experience, which offers the most positive experience and which stays in memory will win in the competition of experiences. (Pine and Gilmore 2011.) Generally speaking, the experience research is struggling between a quantitative approach to obtain generic results that can be applied for management and experience production, and qualitative approaches, to understand the specific qualities at the personal level. Probably, we will never reach a complete understanding of personal experiences, but maybe, with the trials, we can obtain conceptual maps or models, and identify the dimensions and factors affecting the experience (see Gelter 2011). Our perspective is mainly economic, even if we take the psychological perspective when analyzing the diaries written by the research subjects. We use both quantitative and qualitative approaches in our research. Companies should offer situations and facilities that enable tourists or guests to create experiences together with the companies (Lüthje and Tarssanen 2013).

Physical properties of cold in producing arctic conditions

The crucial problem in producing artificially arctic phenomena is most often how to speed up processes that in nature occur over a long period. The long duration of the processes is due to the natural limitations coming from the thermodynamic properties of water, i.e. very high specific heat capacity and large specific latent heat of fusion and vaporization that all are a result of the strong hydrogen bonding between water molecules. Nevertheless, there are also Arctic phenomena where we meet an amazing fastness in spite of the thermodynamic properties of water mentioned above. In the following two sections, we consider examples of these phenomena on the basis of thermodynamics.

Artificial snow versus natural snow

The artificial snow from snow cannons looks like snow and is perfect material, for example, in building big structures like snow castles. In snow cannons, small water droplets are rapidly frozen in fast moving cold air, also partly stuck with each other. The out coming snow consists of small ice grains. It is quite hard and has a high density of $0.5 - 0.7 \frac{kg}{m^3}$, which implies that the process consumes a lot of water. Artificial snow is also used at ski resorts to supplement natural snow.

We can illustrate the problem of making artificial snow with snow cannons by first considering the cooling of a water droplet in a cold air stream. We use the common Lumped Capacitance Method that is presented, for example, in Incropera et al. (2007). This method is usually applied for solid material, since it does not consider the effect of evaporation. The principle of the method stays in energy conservation: In convection, the heat transfer from the water surface to the air equals to the change of internal energy of the water that comes true as a drop of inner temperature of the droplet. The influence of radiation on the cooling is regarded as negligible due to many water droplets at the same temperature. The energy conservation can be expressed by the following differential equation

$$-hA(T - T_\infty) = \rho V c \frac{\mathrm{dT}}{\mathrm{dt}} \qquad (1)$$

In equation (1), we denote the symbols as follows:

T_∞ = Temperature of the surrounding air [K]
T = Temperature of water droplet [K]
ρ = Density of water in temperature T
c = Specific heat capacity of water (at constant pressure)
V = Volume of water droplet
A = Surface area of water droplet
h = Heat transfer coefficient of air

If we presume that the internal temperature gradient of the water droplet is uniform and the volume of the water droplet is constant during cooling, equation (1) can be solved for time t with the initial temperature of water denoted as T_i:

$$t = \frac{\rho V c}{hA} \ln\left(\frac{T_i - T_\infty}{T - T_\infty}\right) \qquad (2)$$

The crucial factor in equation (2) is the heat transfer coefficient h that is influenced by many other factors that impact the water surface among other things the geometry of the surface and, especially, the velocity and the humidity of the air stream. Typically in the forced convection of air, h has a value of less than $100 \frac{W}{K\,m^2}$. Applying formula (2) for water droplets we get, for instance, the following estimation: The cooling of a 7°C water droplet of diameter of 1 mm in -5°C air to freezing point takes near 7 seconds when value $100 \frac{W}{K\,m^2}$ is used for h.

There are no common models for estimating the freezing rate of water. A water droplet may easily be supercooled several degrees below freezing point, in which case the freezing can occur almost instantly as in the natural phenomena known as glaze-ice and rime (Depenedetti and Stanley 2003.; Weather Online Weather Facts 2014.). However, the specific latent heat of fusion of water, $334 \frac{kJ}{kg}$, must be released out of the droplet during freezing. That is over 10 times more than with the released heat in cooling from 7°C to freezing point.

The estimated cooling time and the large released latent heat reveal that there must also be other significant, influencing factors. The evaporation of water droplets shortens the cooling time significantly. The large latent heat, $2260 \frac{kJ}{kg}$, absorbed by evaporated water molecules can make the temperature of small water droplets to drop very quickly. If the surrounding air becomes saturated by water vapor, the influence of vaporization on cooling vanishes due to the reached equilibrium with condensation. That is why it is very difficult to make artificial snow with snow cannons when the relative humidity of the air is high. The pressured air expands in the process, and the speed of the pressured water increases in the nozzle, which both decrease the temperature of water droplets. After all, the above consideration demonstrates that converting water rapidly into artificial snow in a cold air stream is limited by many conditions. There are also solutions for making artificial snow that do not depend on weather conditions such as the process of mechanical vacuum freezing technology (see All Weather Snowmaker 2014). This technique is not as widely spread as the traditional and lighter solution produced by snow cannons.

For Arctic experiences there is also a need for snowfall. If we want to produce natural snowflakes falling down slowly perhaps in an interior, the common commercial snow cannons are not the most appropriate equipment. There are various atmospheric conditions where natural snowflakes can be formed. The heavy snowfalls are typically formed within clouds where warm air with high humidity is in a strong upward motion and the atmosphere is cold enough. The seed of a snowflake is formed from a supercooled water droplet (about 10 μm in diameter) having some impurity, for instance, an aerosol particle in it (Christner et al. 2007). The frozen crystal seed grows by deposition of water vapor in a complicated and long-term process where the most essential is that the surrounding air is supersaturated and the temperature of the atmosphere is suitable. The final shape and structure of the falling snowflake is determined by its random and erratic motions through the atmosphere. Supersaturation is a state of air where it includes more water vapor than the saturation temperature of the current pressure would expect. This is not a steady state but can arise from delays in the condensation of water vapor.

There are countless shapes of snowflakes because they can be formed from individual snow crystals or from a few crystals stuck together. Through the works of researchers such as Nakaya, Furukawa, and Libbrecht, among others, we know much about how snow crystals grow and how snowflakes are formed. Unfortunately, the detailed kinetics of how water molecules incorporate into snow crystals and the growth rate of ice crystals is not yet well understood (Libbrecht 2004). In laboratory experiments, the growth rate is found to be very slow, which is seen, for example, in Fig. 2 (Yokoyama and Kuroda 1990). The growth of a snow crystal by faceting to the size of less than one millimeter can take hours.

The first laboratory study of growing snow crystal forms was performed by Nakaya in the 1930s (Libbrecht 2005). Nakaya combined his observations into the snow crystal morphology diagram, which is shown in Fig. 3. The diagram shows that the shape of a growing ice crystal is affected by two physical conditions; the temperature and the degree of supersaturation of the surrounding air. For the fast forming of a snowflake from ice crystals, the dendrite forms are the most appropriate. An increasing supersaturation at a temperature of $-15°\text{C}$ perturbs the faceting and brings out more complicated shapes by branching. Libbrecht (2004) found that the growth of larger crystals is governed by the diffusion of farther vapor molecules to the surface. The structure itself yields limitations in diffusion, which leads to the branching and formation of arms to the crystal. Kallungal and Barduhn (2004) found the thermal convection of heat transfer to be one important controlling mechanism for the growth rate. Unfortunately, a literature search of ice crystal growth does not show a final recipe for preparing large snowflakes quickly.

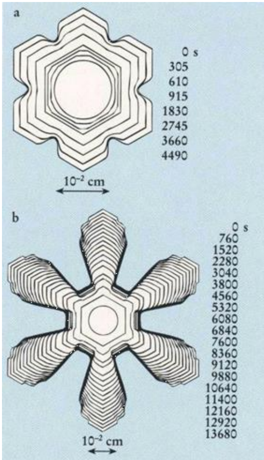

Figure 2. Time-sequence illustration of a growing snow crystal. The Figure was adapted from Furakawa.

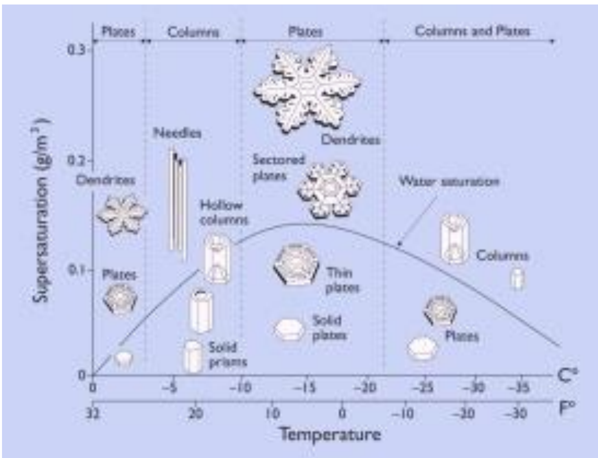

Figure 3. The snow crystal morphology diagram. The figure was adapted from Furakawa.

In 2008, Snaterse conducted examinations in the AP laboratory for making natural snow in the project A Recipe for Natural Snow. The test configuration includes a separate humidifying box with a shower system and the cold chamber where snowflakes of approximately 100 μm were formed. The measured specific weight of the produced snow was between 110 and 215 $\frac{kg}{m^3}$, which is in the upper range of the natural snow density 30 and 200 $\frac{kg}{m^3}$. The tests took at most half an hour. One crucial issue for longer term tests proved to be the difficulty faced in keeping the temperature of the chamber constant. (Snaterse 2008.)

Frost

An opposite phenomenon to the slow formation of ice crystals from water vapor is the amazing quick formation of frost in cold air from hot water. This can be tested by everyone in winter time. When a cup of hot water is thrown into cold air (at least 15-20 degrees below zero), this impressive phenomenon will take place (see Fig. 5). The thermodynamic reasoning for the amazing phenomenon can be driven from equation (3) established by Irving Langmuir (1881-1957) which gives the theoretical maximum evaporation rate of water (see Dennis 2014).

$$\dot{m} = (p_w - p_a)\sqrt{\frac{M}{2\pi R\,T}} \tag{3}$$

In equation (3), we denote the symbols as follows:

p_w = Vapor pressure in water [Pa]
p_a = Partial vapor pressure in air [Pa]
M = Molar mass of water [kg/mol]
R = Molar gas constant
T = Temperature [K]

The partial vapor pressure of cold air is at most a few percent of the vapor pressure of hot water. The large pressure difference yields very high evaporation rates by equation (3), which is illustrated in Fig. 4, where a temperature of -10°C is used for the air.

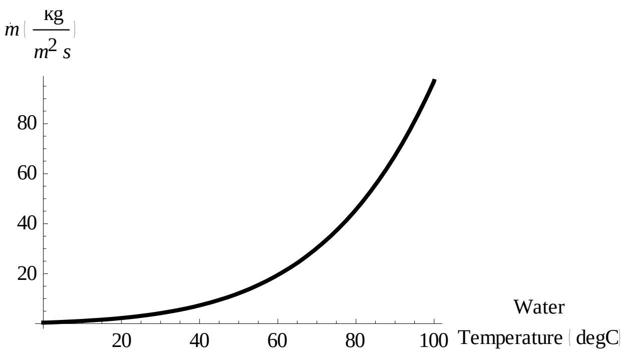

Figure 4. The Maximum evaporation rate of water by Langmuir's equation.

Figure 5. Fast evaporation of hot water in cold air

The crucial thing that prevents the evaporation rate from increasing to the maximum in normal conditions is that the air in a very thin boundary layer becomes rapidly saturated, which leads to a steady state between evaporation and condensation. Only a part of the vapor in the boundary layer diffuses farther away. The fast evaporation rate can be reached in a very extreme condition of a rapid cold air stream where the boundary layer is replaced by new cold air before it becomes saturated. The surrounding cold air is soon saturated by the vaporized water that deposits rapidly into small ice crystals forming a frost cloud (see Fig. 5). When a small water droplet is in an air stream, a pressure difference in the flow direction is formed due to a turbulent boundary layer. It is obvious that reduced pressure on the water surface may start boiling in the droplet that then splinters the droplet and quickens the vaporization.

In the experiments in the AP Laboratory, the maximum evaporation rate conditions were found to be reached when pressured hot water at a temperature of approximately 70℃ was sprouted through a nozzle into cold air at a temperature of at most -5℃. Applying Langmuir's equation (3) to a small water droplet in these conditions, the time needed to vaporize the droplet is less than one millisecond. This technique can be used, for example, to produce frost steam in interiors. The frost can be produced from pure water without any other chemicals or particles, unlike with the theatrical fog and smoke.

Case study: Sleeping in a snow castle

The objective of the study was to find out, using a multicultural test group of foreign exchange students, how a night's sleep in the snow hotel compares with a night's sleep at home in terms of physiological recovery and relaxation. The subjects also reflected their subjective experiences in personal diaries.

We used Firstbeat's analysis technology to measure the degree of physiological recovery in the body. The analysis technology, developed by the Finnish company Firstbeat Technologies, is based on heart rate analysis. Analysis software processes the heartbeat data accumulated in the heartbeat recorder. On the basis of the analysis, it is possible to determine various heart rate variables and indicators. (Firstbeat 2008.)

The autonomic nervous systems and heart rate variability (HRV)

The most important of the systems controlling and coordinating bodily functions is the nervous system, functionally divided into the somatic nervous system, responsible for stimulating muscle contraction, and the involuntary or autonomic nervous system (Leppäluoto et al. 2008). The autonomic nervous system controls the functions of the visceral organs in the body, affecting blood pressure, heart rate, digestion, micturition and body temperature. The operation of the autonomic nervous system is controlled by nuclei located in the spinal cord, brainstem, hypothalamus and the limbic system in the cerebral cortex by means of afferent (carrying nerve impulses toward the central nervous system) and efferent (carrying nerve impulses away from the central nervous system) nerve fibres. (Guyton 1991.)

The autonomic nervous system is divided into sympathetic and parasympathetic systems which innervate the same internal organs but, as a rule, have opposite effects on the bodily functions. They do not, however, compete with each other but operate in different situations. The sympathetic nervous system primes the body for action by stimulating the contraction tendency of the cardiovascular system, dilating the blood vessels in striated muscle tissue and bronchus and inhibiting intestinal and bladder action – this is called the fight-or-flight response. The parasympathetic nervous system assists physiological recovery by stimulating activities which occur when the body is at rest: it slows down the heart rate and accelerates digestion. The balance between the sympathetic and parasympathetic nervous systems varies depending on whether we are asleep or awake. During sleep, the parasympathetic division is dominant. Changes of mood also affect the operation of the sympathetic nervous system. (Sovijärvi et al. 2003; Leppäluoto et al. 2008.)

Heart rate refers to the succession of heartbeats generated in the sinoatrial node located in the wall of the right atrium of the heart. The heart rate continuously varies in a cyclic fashion: this is called heart rate variability, or HRV (Sovijärvi et al. 2003). The heart rate variability refers to the variation in the time interval between heartbeats. The variation is affected by the activation levels of the sympathetic and parasympathetic divisions of the autonomic nervous system. The cardiac muscle responds to the activation of the parasympathetic nervous system in a couple of milliseconds, resulting in a high-frequency HRV. The sympathetic nervous system has a slower response, a few seconds, resulting in a low-frequency HRV. (Laitio et al. 2001.)

The cardiac cycle can be represented by means of electrocardiography (ECG). An electrocardiogram is a pattern reflecting the electrical activity of the heart in the time domain. In the ECG tracing (Fig. 6), we can recognise various stages of operation of the atria and ventricles. The first deflection in the graph is called the P wave and it represents activation of the atria; in the PQ interval the impulse travels from the sinus node to the ventricles; the QRS complex represents contraction of the ventricles; in the ST interval the ventricles remain contracted; and during the T wave the ventricles relax. (Leppäluoto et al. 2008.) The interval of successive R peaks is called the heartbeat interval (Firstbeat 2008).

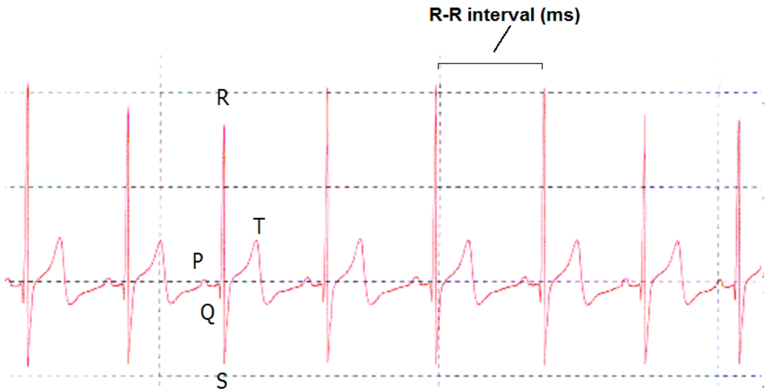

Figure 6. An ECG tracing where the RR interval represents the temporal distance between two consecutive heartbeats (Firstbeat 2008).

Firstbeat – well-being and HRV analysis

The Firstbeat well-being analysis tool uses time and frequency domain analyses to produce an analysis of the heart rate variability from the accumulated heart rate data. In the time domain analysis, the temporal variation in the duration of the RR interval is analysed statistically. One example of time domain analysis tools is the Root Mean Square of Successive Differences (RMSSD) method to calculate the square root of the mean of the sum of the squares of the successive differences between adjacent RR intervals. Frequency domain analysis is a spectral analysis based on the assumption that the sympathetic and parasympathetic nervous systems have characteristic frequency bands of their own. Frequency domain analysis uses three separate frequency bands for the HRV.

- The high frequency (HF) band, 0.15–0.40 Hz
- The low frequency (LF) band 0.04–0.15 Hz
- The very low frequency (VLF) band 0.0033–0.04 Hz (Firstbeat 2008).

A high frequency HRV is an indicator of the activity of the parasympathetic nervous system. A low frequency HRV is considered to indicate activity in both the sympathetic and parasympathetic divisions (Sovijärvi et al. 2003).

Methods and procedures

The test group consisted of 12 volunteers, who were young foreign exchange students studying in Finland (6 female and 6 male, on average 22 years old, ranging from 18 to 31 years). Their stay in Finland had lasted on average for 12 weeks prior to the experiment (ranging from 5 to 20 weeks). The volunteers were of Polish, Spanish, British, Czech, Chinese, Russian, German and American (US) nationality. Before the experiment was started the participants were given a briefing. In the briefing it was explained to the participants how the experiment would proceed, how to use the heartbeat recording device and how to enter data in the electronic diary. Each participant signed a written consent form. The level of physiological recovery was determined by measuring the balance of the autonomic nervous system on the basis of HRV analysis. The HRV analysis was carried out using the Firstbeat well-being analysis tool developed by Firstbeat Technologies.

Heartbeat data were collected for a continuous period of 72 hours using the Firstbeat Bodyguard heartbeat recorder. The heartbeat recorder and the associated software have been utilised in several studies on the physiological workload (e.g. Rusko et al. 2006; Martinmäki 2009; Hynynen 2011). The measurement data collected were analyzed to produce a physiological recovery index (RMSSD index) for the sleeping periods within the 72 hours and a physiological relaxation index for the three days of measurement. The sleeping period of the first night took place at the normal place of accommodation of each particular student, the second night was spent in a double room at the snow hotel and the third night at the normal place of accommodation again. After each night, participants reported on the quality of their sleep in their electronic diaries. The normal daily rhythms of the participants were not standardised for the duration of the study.

Analysis and results

The heartbeat data from the measurements was analysed using the well-being analysis software. In the heartbeat data analysis, the HRV signal is processed in several calculation steps.

The measurement data was processed by the analysis programme to create a data export file containing numerical data over a desired period of time for statistical processing. With the Firstbeat well-being analysis software it is possible to measure physiological reactions during the measurement period. In this study we utilised the data export file to obtain a relaxation index describing the activation level of the parasympathetic nervous system during the measurement period and an RMSSD index describing the mean variation of successive heartbeat intervals in milliseconds as a five-minute average in order to determine the activation levels of the autonomic nervous system. In the Firstbeat analysis, a rising RMSSD index and relaxation index correspond to better physiological recovery.

The statistical analysis was carried out using the analysis function of Microsoft Excel 2010. The analysis was based on frequencies, means and standard deviation. The difference of RMSSD indexes and Relaxation indexes between preceding and following time of the snow castle night was tested by the SPSS 15.0 statistical analysis software using the Wilcoxon Ranked Sign Test (WRS Test).

The average duration of the sleep period recorded by the participants in their diaries was 9h 15min (ranging from 8h to 11h 15min) for the first night, 8h 15min (ranging from 7h 15min to 9h) in the Snow Castle, and 7h 30min (ranging from 4h 15min to 10h) for the third night. The average sleeping time for all three nights was 8h 15min.

Physiological recovery was measured using the RMSSD index by comparing measurement data from the night spent at the snow hotel to the measurement data from the preceding and following night. According to the results, 80% of the participants experienced a better physiological recovery during the stay in the snow hotel than during the nights spent at home (p-value from WRS Test 0.007 for the preceding night and 0.002 for the following night). (Fig. 7)

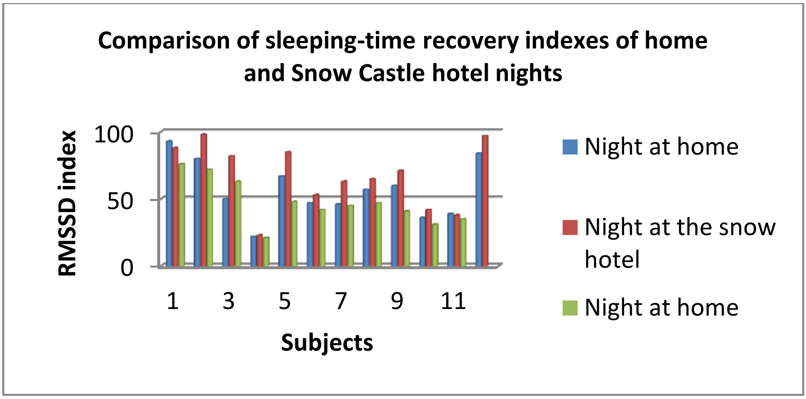

Figure 7. Physiological recovery based on the RMSSD index

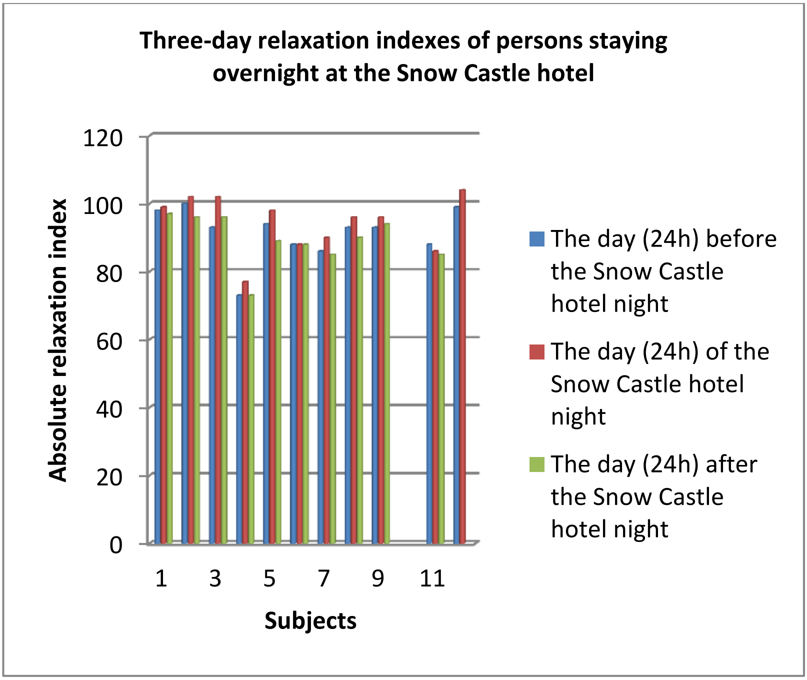

Figure 8. Relaxation indexes of the participants during the three measurement days (data of subject no. 10 is missing and the 24-hour data of the third night of subject no. 12 is missing).

Physiological relaxation was determined by comparing the relaxation indexes of the days, i.e. 24 hour periods, of the measurement period. According to the results, 82% of the participants experienced better relaxation during the stay at the snow hotel than during the days spent at home (p-value from WRS Test 0.11 for the preceding day and 0.005 for the following day). (Fig. 8)

Discussion

Because of the small sample in the case study, the results cannot be generalized, but they show a certain trend. On the basis of the study foreign exchange, students experienced a better physiological recovery during the night that was spent at the snow hotel than during the nights spent at home. In addition, the 24-hour degree of relaxation during the stay at the snow hotel was higher than at home. Therefore, it seems that the stay at the snow hotel was physiologically beneficial to the participants and increased their well-being through positive experiences.

As mentioned before, the multicultural test group also reflected the experience of sleeping a night in the snow hotel in diaries. Most of the respondents described the night in SnowCastle as a positive – once in a lifetime – experience. According to the reflections in the diaries, 45% of the participants felt that they did not sleep well at the snow hotel, but the results of the measurements indicate that they had recovered better than during the home nights. 10% of the participants felt that they did not sleep as well at the snow hotel as at home, and according to the measurements their recovery during the hotel night was indeed inferior to that of the home nights. Reasons for a poor night's sleep included feeling cold, especially in the facial area, and not being accustomed to sleeping in a sleeping bag.

In our case study, we did not determine the reasons behind the results. Are the results a consequence of an experience caused by the overnight stay at the SnowHotel, sleeping at –5°C, spending leisure time in a pleasant environment among nice people, or some other reason? Would we have obtained the same result if the test group had spent the night in a normal hotel environment? These are interesting questions that, if we want to study them, require different settings. In this study, the normal daily rhythm of the participants was not standardized for the measurement period. The participants were allowed to exert themselves as much as they desired both mentally and physically. Furthermore, the amount of sleep was not standardized at any point of the study. For three participants, the night following the snow hotel night was clearly shorter than the two preceding nights. For these three persons, the result for the third night and day may, therefore, be unreliable. If we would have standardized all the participants' sleeping times according to the shortest sleeping time, each participant would have lost four hours of sleep. As a result, we would have lost a lot of measurement data, and from the point of view of the problem studied it would have been meaningless to process the data after that.

Conclusion

There is a clear need for new products and innovations and new Arctic wellness services. Globally, there has emerged a growing interest toward experiences in Arctic conditions. Tourists, for example, are constantly looking for new spectacular experiences such as spending a night in the Arctic winter. Traditional goods and services are no longer enough and no tourism related organization or destination can today afford to provide basic service activities and ignore its guests' experiences. Arctic circumstances have the capacity to offer exciting opportunities for today's tourist. This creates new demands for product development in Arctic wellness services.

On the basis of our case study, it seems that the multicultural test group experienced a better physiological recovery during the night spent at the SnowHotel than during the nights spent at home. In addition, the 24-hour degree of relaxation during the stay at the SnowHotel was higher than that of the home nights. Therefore, on the basis of the results, it seems that the stay at the SnowHotel was physiologically beneficial to the participants and increased their well-being. Furthermore, in the diaries, the experience was described as a once in a lifetime experience.

Today's Arctic tourism services need to be produced artificially to prolong the season. New innovations are based on the understanding of the physical properties of cold in Arctic phenomena. In spite of the extensive research conducted, there are still phenomena related especially to the behavior of water in cold conditions in which there is no exact thermodynamic model. Our research shows that, although cold is often associated with discomfort rather than comfort, it provides versatile opportunities to develop new wellness services.

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