Range of motion assessment of elderly arthritis sufferers at Montana (USA) Radon Health Mines

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Abstract: Radioactive radon therapy is a little-known pain relief modality in the US, although it is an accepted therapeutic choice in many parts of Europe and Japan. Radon therapy has been extensively studied by European and Japanese physicians and scientists but information about the specific therapeutic applications of radon in the US is limited to anecdotal and ethnographic data. The purpose of this pilot study was to use range of motion measurements to evaluate the effect of radon therapy on joint flexibility in elderly arthritis sufferers at the Free Enterprise Radon Health Mine in Montana (USA). Finger, shoulder and/or neck flexibility of 21 participants were measured before, during and after a course of radon therapy, using a goniometer and an arthrodial protractor. Results were mixed but indicate overall patterns of improvement. Larger controlled studies should be undertaken to test joint flexibility and other quantifiable effects of radon therapy.

Keywords: arthritis; joint flexibility; low-dose radiation; radon; therapeutic applications.

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1 Introduction

Radon (Rn-222) therapy has a long history of use in many parts of Europe and Japan as an analgesic and anti-inflammatory treatment for various forms of arthritis and other related health problems (Becker, 2004). In the US, however, radon therapy remains a little-known pain relief modality, available at only at a few places in the state of Montana. Although the therapeutic use of radon has been extensively studied and tested by physicians and scientists in Europe and Japan (e.g. Falkenbach et al., 2005; Yamaoka et al., 2004), most of the information about its use in the US is limited to anecdotal and

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ethnographic data (Erickson, in press, 2000). The small pilot study described in this article was designed to address this limitation, with the hope that it would be only the beginning of quantitative data collection at US radon facilities. In this study, finger, shoulder and/or neck flexibility were measured in twenty-one volunteers who were mine clients during the summer of 2005 at the Free Enterprise Radon Health Mine in Boulder, Montana. The goal was to identify any patterns of improvement in the range of motion capability of the participants over a 7–10 day course of radon therapy.

2 Therapeutic use of radon

Radon's analgesic and anti-inflammatory properties are useful in treating a wide variety of conditions, including arthritis, rheumatism, fibromyalgia, psoriasis, asthma and bronchitis. The therapeutic use of radon involves the intake of radon gas either through inhalation or by transcutaneous resorption of radon dissolved in bath water. Most of the radon taken up is subsequently discharged through exhalation but a small amount remains in the body as radioactive radon progeny, which are physiologically active through their continued decay (Becker, 2004). Advocates of radon therapy believe that, at therapeutic doses, radon relieves arthritis pain and inflammation quite effectively. Because its effects are long lasting and because it is relatively inexpensive, radon treatment allows many arthritis patients to discontinue using their conventional medications for months at a time, thus providing relief from the side effects and high costs of medication simultaneously (Erickson, 2000, 2004).

Two important questions about radon therapy make it controversial in the US. The first question is the potential harm from exposure to radon: according to the most recent information available on the internet site of the US Environmental Protection Agency (EPA), radon is the second leading cause of lung cancer in non-smokers (EPA, 2005). This claim is based not only on epidemiological studies of lung cancer in uranium miners (Duport, 2002; Lubin et al., 1994) but also on recent meta-analyses of household radon and lung cancer rates that indicate some correlation of risk of lung cancer with increasing radon concentrations (e.g. Darby et al., 2004). Contrary to this correlation, other research suggests protective, rather than harmful, effects resulting from exposure to environmental radiation such as radon. For example, regions with high background radiation appear to have lower cancer rates than do populations in regions with low background radiation (Becker, 2003; Jagger, 1998; Kondo, 1993). Cancer rates of populations living near the Misasa radon hot springs in Japan have also been compared with rates in non-exposed populations (Mifune et al., 1992) and the connection of radon exposure to activation of cancer suppressor genes examined (Yamaoka et al., 2005).

The second question is whether or not, irrespective of cancer risk, radon therapy is actually effective as an anti-inflammatory and pain reliever. In fact, there is a great deal of evidence for radon's effectiveness, based on work at some of the many radon treatment facilities in Europe, such as the Gasteiner Heilstollen in Badgastein, Austria. In an early study reported by Henn (1956), 3062 arthritis patients were treated at Badgastein between 1949 and 1954. Of these, 1643 patients (53.7%) were 'considerably improved at the end of the treatment', and 1208 maintained their improvement for three to nine months. Henn suggested that radon, combined with hyperthermy, exerted an influence on the autonomic nervous system and activated the pituitary-adrenal system. He also noticed that illnesses for which corticotrophin (ACTH) and cortisone would be prescribed were the ones most helped by the radon therapy (Henn, 1956).

The brochures published today by the Gasteiner Heilstollen make similar claims, that radon absorption 'results in marked relief of pain and improved flexibility'. Heat and radon are thought to work together, boosting blood supply to the skin and thus penetration of radon into the blood stream. Through both penetration and inhalation, radon spreads throughout the whole body, where it accumulates in fatty tissue such as the hormone-producing endocrine glands and emits alpha particles. These alpha particles, the brochure claims, will 'stimulate cellular metabolism and greatly strengthen the body's resistance and repair systems' (Gasteiner Heilstollen Brochure, n.d.).

The Gastein clinic attracts many patients suffering from rheumatoid arthritis, the most severe form of inflammatory arthritis and ankylosing spondylitis, an arthritic condition of the spine. Falkenbach et al. (1996) reported on a study of fifty ankylosing spondylitis (AS) patients at Gastein whose blood was tested for C-reactive protein, a biochemical indicator of inflammation. After four treatments C-reactive protein was significantly decreased, although the cause of this improvement was not clear. Other studies have indicated that pain, stiffness, mobility and walking ability of rheumatoid arthritis patients improved significantly after radon therapy (e.g. Falkenbach, 2001). Further, in randomised, sham-controlled studies (Franke et al., 2000) statistically significant pain relief and increase in function for members of the radon-treated group were seen. Falkenbach et al. (2005) reported on a meta-analysis of five clinical trials with a total of 338 patients, in which there was significantly better and longer lasting pain-reduction in the radon groups than in the control groups.

In part because of the potential risk of lung cancer from radon inhalation, many clinics and spas in Europe prefer to provide radon treatment via bath water. Franke et al. (2000) provide a good overview of the mechanisms thought to be operating during therapeutic radon exposure in bath water. The skin is thought to be primarily responsible for the incorporation of radon (Jöckel, 1997). In radon baths with active ventilation of room air, warm water infused with CO_2 increases blood circulation and thus the uptake of radon into the bloodstream. It has been suggested that radiation acts on the morphological structure of skin in much the same way as topical steroids (Pratzel and Artmann, 1990). Because incorporated radon tends to accumulate in fat, it may stimulate the secretion of corticoids from the adrenal cortex, as shown in experiments with animals (Pfaller, 1979). Radon also appears to stimulate free-radical scavenging enzymes that may help to relieve pain by inhibiting rheumatic inflammation to some degree (Frick, 1988).

The studies described above are only a small sampling of the research worldwide about the potential uses of radon (or other kinds of low-level radiation) in the world's medicine kit. However, despite the amount of research elsewhere, radon therapy in the US remains virtually unstudied and completely off the map of the biomedical health care system.

3 Radon therapy in Montana (USA)

Currently there are four 'radon health mines' in operation in Montana, literally old mines that stopped selling ore in the 1950s and instead opened their doors to arthritis patients. Unlike European radon spas and clinics, where medical doctors examine patients and prescribe specific doses, radon 'therapy' in these mines is self-treatment in which people simply enter the mine and spend one or more hours during which they will take up, by inhalation, the radon gas emanating from the uranium-bearing ores in the mine tunnel. For many years a treatment regimen of about 32 hours over a ten-day period was the recommended exposure but, currently, mine clients are more likely to take anywhere from 30 to 60 hours over ten days. While in the mines, people sit on chairs and padded benches placed alongside the tunnel walls where they may read, sleep or sit and talk with one another. Another popular pastime while in the mines is to sit at tables and play cards or board games. Between visits, the mine visitors are urged to rest, breathe deeply and drink plenty of water. Mine clients are not supervised but rather are expected to keep track of their time in the mines in conformity with the suggested time limits. An honour system assumes that the clients will take only the number of 'treatments' they have paid for.

No medical personnel of any kind are available on the premises and no medical records or referrals are required for admittance, although all of the mines recommend that neither pregnant women nor children under the age of eighteen should use the mine without the express prescription and advice of a licensed physician. The Department of Health and Environmental Sciences of the State of Montana does not actively regulate these mines; they have taken a 'hands off' approach and do not inspect the mines or test the levels of radon on a regular basis (Patricia Lewis, personal communication).

4 Study setting: the Free Enterprise Radon Health Mine

Approximately 500 people visit the Free Enterprise Radon Health Mine every year and many of these are repeat visitors who have been coming to the mine for years. Many people I have interviewed state that after spending two weeks at the Free Enterprise they stop taking their medication and remain relatively pain-free for as long as a year. Several describe that, in the months following their radon treatment, they will gradually notice the return of their symptoms which they understand to be an indication that 'it's time to go back to Montana for a tune-up'. Some clients are able to stretch their visits to one every other year.

The vast majority of mine clients suffer from arthritis and other rheumatic ailments. Other complaints include respiratory illness, skin problems and allergies, as well as diseases such as scleroderma and lupus. Most of the clientele are over the age of 65, with approximately equal numbers of males and females and many married couples. Of the 807 individuals I sampled in a survey of mine records, 83 had been using the mine for twenty years or more and 173 for ten years or more, indicating a high level of satisfaction with radon therapy.

Radon in the US is measured in pico Curies per litre of air (pCi/l). Radon tests at the Free Enterprise Radon Health Mine were done in August 2005 and analysed by Energy Laboratories in Helena, Montana. According to the lab reports, radon concentrations in the mine tunnel were variable by location, with 1800 pCi/l in the north end, 1510 pCi/l in the centre and 1280 pCi/l in the south end of the tunnel. Mine clients typically have favourite spots and sit in different parts of the mine tunnel according to their desire. The radon concentrations are not posted in the tunnel (although the information is available upon request) thus the radon concentration of a particular area is not a significant factor in the choice of where to sit.

5 Study participants and methods

Twenty-one mine clients self-reporting symptoms of joint pain and stiffness were recruited to participate in this study. The group was composed of ten males ranging in age from 53 to 81 and eleven females aged 30 to 77. All participants stated they had osteoarthritis (OA), rheumatoid arthritis (RA) or both. In addition, among the women one had scleroderma, one had fibromyalgia, one had systemic lupus erythematosis (SLE) and one had emphysema. One man had gout. One woman had recently had surgery on her back and neck and one man had had arthroscopic surgery on both knees within the past year.

The range of motion for selected joints of the hand was tested using a goniometer to measure the angle of flexibility. A goniometer is a measuring instrument that measures the amount of motion available at a joint by placing the two arms of the goniometer along the bones immediately proximal and distal to the joint in question. Techniques for using the goniometer were briefly demonstrated to me prior to the study by a faculty member in the Kinesiology Department at California State University, Fullerton, supplemented by *Measurement of Joint Motion: A Guide to Goniometry* (Norkin and White, 2003). An arthrodial protractor, a flat plastic board marked with lines indicating the degree of angle, was used to measure shoulder complex abduction and neck flexibility.

The type of test performed on each individual varied according to that person's unique physical conditions and symptoms. Because most of the participants complained of pain and/or stiffness in their fingers, flexibility at the proximal interphalangeal (PIP) and metacarpophalangeal (MCP) joints were tested for 20 of the 21 individuals. Likewise, shoulder complex abduction was measured for the 11 individuals complaining of stiff or painful shoulders and neck flexibility measured for seven people. These particular joints were selected for this study because they were minimally invasive and did not require the participant to lie down or disrobe. For PIP and MCP joints, participants were asked to flex each joint as far as they were able to do without pain. Angles of flexion obtained were measured with the goniometer, noted and later converted to decimal figures. For shoulder complex abduction, participants were asked to stand with arms straight down at their sides. Standing straight with shoulders level and keeping the arm straight, participants raised first the right arm, then the left, out to the side and as far up alongside their heads as possible without discomfort. Standing behind the person, I measured the maximum angle to which the arm was raised using the arthrodial protractor. Side-to-side neck flexibility was measured by holding the arthrodial protractor perpendicular to the head, centred under the chin. The participant was then asked to turn his or her head first to the right and then to the left, as far as possible without feeling discomfort.

For each participant, the relevant joints were tested at least three times, spaced at relatively equal intervals. The first measurement was taken as a baseline, ideally before radon therapy had been started or as close to the start as possible. For participants staying ten days, second and third measurements were taken at approximately the third and seventh days of therapy. For participants staying only seven days, a second measurement was taken at about the third day. The final measurement was taken when all radon therapy had been completed. It was not possible to test all participants at uniformly identical hours of exposure because of each individual's preferences and activity schedule. Therefore, the equal spacing of tests was worked out with each person individually, without regard to the schedules of the other participants. For example, participant #1 was measured at 0, 12, 24 and 38 h, participant #6 was measured at 0, 14, 26 and 44 h and participant #16 was measured at 2, 17, 37 and 52 h. Separate data sheets were used for each successive measurement to avoid bias from seeing previous measurements. In addition, results were not shared with the participants at the time of measurement to avoid bias.

6 Results

The results of this study were mixed but show an overall pattern indicating some level of improvement. Twelve of the twenty-one participants showed improvement in every, or nearly every, finger joint. The other eight participants showed improvement in some but not all, of their finger joints. In all cases there was a positive net change between first measurements taken before radon therapy and last measurements taken after radon therapy, indicating overall improvement. Total net improvement per person (combined scores for each person's 20 finger joints) ranged from a high of 451.12 to a low of 30.61 degrees. Mean finger joint improvement for each person ranged from a high of 22.56 to a low of 1.53 degrees (See Table 1).

Some of the most clear cut results were seen in the change for range of motion in shoulder abduction. Six participants complained of having one particularly stiff and painful shoulder when they began their radon therapy. For example, participant #12 had decided to try radon therapy for the first time solely because of her neck and shoulder stiffness, especially her right shoulder (see Table 2). After 18 h of radon exposure, her right shoulder improved from a baseline measurement of 105 to 140 degrees. Her neck flexibility improved after 45 h exposure from 40 degrees on the right and 35 on the left, to 70 and 75 degrees, respectively. In another example, participant # 16 could raise his right arm only to a 90 degree angle at the start of treatment. After treatment (52 h exposure total), he was able to raise this arm to a 150 degree angle (see Table 3). Although 180 degrees is considered a normal range of motion for shoulder complex abduction (Norkin and White, 2003), this was nevertheless a 60 degree improvement for him.

In fact participant #16, whom I will call 'John', was the most striking example of improvement overall. For the purposes of this study, he was an ideal subject because his symptoms included all of the particular joints I wished to measure. John was a fifty-three year old male, a self-employed wood-worker from Ohio. He described his ailments as osteoarthritis and 'rheumatism or possibly rheumatoid arthritis' which caused pain in his knees, hips, shoulders, neck, feet and hands. He was not able to take aspirin, which he stated made him sick. Remedies he used at home on a regular basis included Arthro-7, zinc, Q-gel+, flaxseed oil capsules and Darvocet 'when desperate'. He and his wife had been coming to Montana in the summer for radon therapy since 1992 and estimated this trip (2005) to be their 12th or 13th visit. On at least one occasion in the past he had experienced such positive results from the radon treatment that he was able to skip one summer. In another year, he had felt badly enough to come to Montana twice during the year.

John's preferred treatment plan was to stay at the mine for ten days, during which time he took an average of 6 h radon exposure per day. He liked to come early in the morning, stay down in the mine for about 2 h, come up for a break and then take another 2 h of radon. After a long lunch break, he would return for a final 2 h. I measured John's finger joints (PIP and MCP), shoulder abduction and right-left neck rotation a total of four times: after 2, 17, 37 and 52 h. At each measurement session, John claimed to feel

Table 1 Age, sex, ailments, radon exposure and improvement for all participants

No.	*Age*	*Sex*	*Ailment(s)*	*Total hours radon*	*Improvement (in degrees)*			
					Hands (net change)	*Hands (mean change)*	*Shoulders (total change)*	*Neck (total change)*
1	77	M	OA in shoulders, hands, back	38	253.99	12.70	10.0	n/a*
2	77	F	OA, RA, emphysema	38	56.87	2.84	n/a	n/a
3	62	M	OA in knee, shoulders, fingers	64	274.44	13.72	n/a	n/a
4	62	F	RA in feet, hands	49	68.35	3.42	n/a	n/a
5	59	M	OA in hands, gout in ankles	28	81.65	4.08	n/a	n/a
6	74	F	RA in hands	44	451.12	22.56	n/a	n/a
7	74	M	OA, RA in back, hands	37	239.36	11.97	15.0	n/a
8	58	F	RA in knees, shoulders, hands	20	222.39	11.12	55.0	n/a
9	81	M	OA in back, neck, shoulders, hip	44	30.61	1.53	10.0	10.5
10	76	F	OA shoulders, back, neck (recent surgery)	45	202.10	10.10	n/a	n/a
11	58	F	OA, RA in neck, fibromyalgia	56	229.99	11.50	37.0	15.0
12	30	F	Neck stiffness and chronic pain	45	n/a	n/a	45.0	70.0
13	77	F	OA, borderline RA in fingers and toes	43	107.06	5.35	n/a	n/a
14	73	M	OA in back, recent knee surgery	49	72.51	3.63	5.0	5.0
15	74	F	Scleroderma, general joint stiffness	33	77.85a	4.10	5.0	5.0
16	53	M	OA, RA, feet, hands, knees, hips, shoulders	52	351.03	17.55	115.0	33.0
17	78	M	OA in shoulders, neck, hands	37	151.63	7.58	30.0	n/a
18	76	M	OA in hands, neck, shoulders	56	157.87	7.89	n/a	5.0
19	75	F	OA, RA in hands, shoulders, lupus (SLE)	56	284.13	14.20	n/a	n/a
20	69	F	OA in hands, feet	41	141.04	7.05	n/a	n/a
21	73	M	OA in hands, feet, shoulders	41	38.39	1.92	27.0	n/a

Notes: *Indicates measurements not taken.
[a]Only 19 joints could be measured on participant #15.

Table 2 Neck and shoulder data for participant #12

Joint	*Participant #12* [a]				
	Measurement #1 (0 h) [b]	*Measurement #2 (18 h)*	*Measurement #3 (45 h)*	*Measurement #4 (n/a)*	*Net change*
Rt shoulder	105.0 [c]	140.0	140.0		35.0
Lt shoulder	130.0	150.0	145.0		15.0
Neck right	40.0	50.0	70.0		30.0
Neck left	35.0	60.0	75.0		40.0

Notes: [a] Only shoulders and neck measured for this participant.
[b] Number of hours exposure to radon at time of measurement.
[c] All number represent angle of joint flexion, in degrees.

Table 3 Measurement data for participant #16

Joint [a]	*Participant #16*				
	Measurement #1 (2 h) [b]	*Measurement #2 (17 h)*	*Measurement #3 (37 h)*	*Measurement #4 (52 h)*	*Net change*
PIP R-1	57.50 [c]	69.50	71.25	69.37	11.87
PIP R-2	57.50	84.27	79.37	80.63	23.13
PIP R-3	57.50	75.00	86.25	91.70	34.20
PIP R-4	47.50	79.37	80.50	85.00	37.50
PIP R-5	69.37	77.50	85.00	82.50	13.13
PIP L-1	65.00	67.50	67.50	66.25	1.25
PIP L-2	63.70	89.37	93.75	101.70	37.95
PIP L-3	81.25	94.37	89.37	93.75	12.50
PIP L-4	77.50	88.35	88.75	82.50	5.00
PIP L-5	83.35	87.50	88.75	84.37	1.02
MCP R-1	55.00	72.50	74.37	72.50	17.50
MCP R-2	69.37	87.50	89.37	97.50	28.13
MCP R-3	82.50	92.50	93.75	102.50	20.00
MCP R-4	82.50	98.35	98.75	112.50	30.00
MCP R-5	78.75	95.00	95.50	100.00	21.25
MCP L-1	70.00	76.25	76.25	75.00	5.00
MCP L-2	84.37	88.75	88.35	95.63	11.26
MCP L-3	91.70	99.37	97.50	102.50	10.80
MCP L-4	90.63	100.63	102.50	109.37	18.74
MCP L-5	91.70	94.37	97.50	102.50	10.80
Rt shoulder	90.0	120.0	140.0	150.0	60.0
Lt shoulder	95.0	115.0	135.0	150.0	55.0
Neck right	50.0	62.0	70.0	70.0	20.0
Neck left	55.0	55.0	65.0	68.0	13.0

Notes: [a] PIP=proximal interphalangeal joint; MCP=metacarpophalangeal joint; thumb=1.
[b] Number of hours exposure to radon at time of measurement.
[c] All number represent angle of joint flexion, in degrees.

improvement in flexibility as well as pain relief. A table of John's results and net change (Table 3) shows a clear pattern of improvement in each joint. The PIP joint net improvement varies from a low of 1.02 degrees (little finger, left hand) to a high of 37.95 degrees (index finger, left hand). MCP joint net values varied from a low of 5.00 degrees (thumb, left hand) to a high of 28.13 degrees (index finger, right hand). Right and left shoulder abduction was initially 90 and 95 degrees, respectively. At the end of radon treatment, both right and left shoulders could be raised to the 150 degree level, a net improvement of 60 and 55 degrees, respectively. Initial right-left neck rotation was 50 degrees to the right side and 55 degree to the left, ending at 70 and 68 degrees, respectively, for a total change of 33 degrees.

7 Discussion

The primary difficulty in evaluating the results from this study is the sheer number of ways individual participants vary from one another. In a setting such as the Free Enterprise Radon Health Mine, individuals using radon therapy suffer from a broad range of ailments and symptoms. Some of these ailments have been formally diagnosed by a physician, other ailments are self-diagnosed and are described in terms of folk categories. Any two persons with OA or RA do not share exactly the same level of pain and other symptoms, nor do they suffer from the disease in the same joints or in the same way. Each person has a unique health history which includes the use of different kinds of medicines in varied dosages. Further, each person uses the radon mine for a different number of hours per day and the total length of their stay varies. Finally, each person's body and metabolism without doubt reacts to radon therapy uniquely, in much the same way as individuals may respond differently to the same medication.

In addition to the variation among radon clients in terms of their medical histories, ailments and medications used, there is obviously, even in these twenty-one participants, a great deal of variation in how each person approaches his or her radon therapy. For some individuals, time and work constraints limit their radon therapy experience to seven days, while others with a more flexible schedule stay ten days or even longer. Each person also has an idea about how much radon exposure per day and how many hours at one time, seems best for them. At this point, we cannot be sure what dose per day and over how many days, is optimal, nor even if radon therapy can be approached that way. Perhaps radon therapy is a treatment that will be optimally effective when a specific dosage is individually prescribed for each person, which is, of course, what radon spas and clinics in Europe currently do.

Another possible confounding factor is the level of radon in the Free Enterprise mine tunnel. Although the owners of the mine try to keep the radon concentration relatively consistent, there is unavoidable variation because of factors such as weather or humidity. There are also differences in radon concentration at various parts of the mine tunnel: Depending upon what spot one chooses to sit in, the level of radon during the study period ranged from 1280–1800 pCi/l. Many radon mine clients, particularly those who have used the mine for a number of years, have come to favour one area of the tunnel over another (without knowing the radon levels), simply because of a previous good experience while sitting there or because there is a more comfortable chair or for any number of other reasons. Thus, one mine client who habitually uses (for whatever reason) the part of the tunnel with the highest (or lowest) radon level may have a different result from another client who sits in a different spot for each exposure session. On the other hand, perhaps the overall exposure in the mine tunnel is enough that these kinds of variations in radon concentration make little difference to the final result.

For all of these reasons, it is clear that in a study such as this, it is extremely difficult to compare one radon client to another. Rather, one can only look at each individual to see how much, if any, that person improved. Nevertheless, I suggest that this study, although small and certainly flawed, shows an overall pattern of improvement that warrants scientific investigation of Montana's radon therapy. For a larger study, a research design should be developed in which participants would volunteer to take radon treatments for the same number of hours, at the same time and on the same days and they should sit in the same area of the tunnel to provide a more consistent exposure.

8 Conclusions

This pilot study attempted to collect quantifiable data that would demonstrate the effect of radon therapy on a range of motion and joint flexibility. Results were mixed but show an overall pattern of improvement. Well-designed, controlled studies on a larger scale are urgently needed to help us learn more about radon therapy in the US. The clientele of the radon health mines in Montana believe this is a therapy that helps to relieve their pain and symptoms. In my ethnographic studies since 1997, as well as in the range of motion pilot study described in this article, mine clients have seemed very willing to help in whatever way they could to make radon therapy more widely known, more acceptable to the medical community and more available to other people like themselves who need affordable alternatives to prescription medications. They are a ready-made study population, waiting only to be asked to participate.

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References

Becker, K. (2003) 'Health effects of high radon environments in central Europe: another test for the LNT hypothesis?', *Nonlinearity in Biology, Toxicology, and Medicine*, Vol. 1, No. 1, pp.3–35.

Becker, K. (2004) 'One century of radon therapy', *Int. J. Low Radiation*, Vol. 1, No. 3, pp.334–357.

Darby, S., Hill, D., Auvinen, A., Barros-Dios, J., Baysson, H., Bochicchio, F., Deo, H., Falk, R., Forastiere, F., Hakama, M., Heid, I., Kreienbrock, L., Kreuzer, M., Lagarde, F., Mäkeläinen, I., Muirhead, C., Oberaigner, W., Pershagen, G., Ruano-Ravina, A., Ruosteenoja, E., Schaffrath Rosario, A., Tirmarche, M., Tomášek, L., Whitley, E., Wichmann, H. and Doll, R. (2004) 'Radon in homes and risk of lung cancer: collaborative analysis of individual data from 13 European case-control studies', *BMJ,* doi:10.1136/bmj.38308.477650.63.

Duport, P. (2002) 'Is the radon risk overestimated? Neglected doses in the estimation of the risk of lung cancer in uranium underground miners', *Radiation Protection Dosimetry,* Vol. 98, No. 3, pp.329–338.

EPA (Environmental Protection Agency) (2005) 'A Citizen's Guide to Radon: The Guide to Protecting Yourself and Your Family From Radon', US EPA 402-K02-006, Revised September 2005, available from: http://www.epa.gov/radon/pubs/citguide.html

Erickson, B. (2000) '...And the people came to the caves to be healed', *The Halcyon Series,* Vol. 22: Western Futures, pp.31–52, Reno: Nevada Humanities Committee.

Erickson, B. (2004) 'The therapeutic use of radon: a biomedical treatment in Europe; an "alternative" remedy in the United States', *Proceedings of the 14th Annual Pacific Basin Nuclear Conference*, pp.600–610, La Grange Park, IL: American Nuclear Society.

Erickson, B. (In press) 'Toxin or medicine? Explanatory models of radon in Montana health mines', *Medical Anthropology Quarterly,* Vol. 21, No. 1.

Falkenbach, A. (2001) 'Rheumatic pain in elderly patients with ankylosing spondylitis during a three-week course of radon-speleotherapy (SK)', *Rehabilitácia,* Vol. 34, pp.171–173.

Falkenbach, A., Gütl, S. and Herold, M. (1996) 'Radon exposure for treatment of ankylosing spondylitis: the effect on serum neopterin and C-reactive protein (CRP)', *Forsch. Komplementärmed*, Vol. 3, p.316.

Falkenbach, A., Kovacs, J., Franke, A., Jörgens, K. and Ammer, K. (2005) 'Radon therapy for the treatment of rheumatic diseases – review and meta-analysis of controlled clinical trials', *Rheumatol. Int.,* Vol. 25, pp.205–210.

Franke, A., Reiner, L., Pratzel, H.G., Franke, T. and Resch, K.L. (2000) 'Long-term efficacy of radon spa therapy in rheumatoid arthritis – a randomized, sham-controlled study and follow-up', *Rheumatology,* Vol. 31, pp.894–902.

Frick, W. and Pfaller, W. (1988) 'Die Auswirkung niedriger α-Strahlendosis auf epitheliale Zellkulteren', *Z Phys Med Baln Med Kilmatol,* Vol. 17, Sonderheft 1, pp.23–31.

Gasteiner Heilstollen Brochure (n.d.) "Unique throughout the world."

Henn, O. (1956) 'Combined treatment by radium emanation and hyperthermy (subterranean tunnel treatment) of Badgastein (Bockstein)', *Munchen. med. Wchnschr,* Vol. 98, pp.365–369.

Jagger, J. (1998) 'Natural background radiation and cancer death in Rocky Mountain states and Gulf Coast states', *Health Physics,* Vol. 75, No. 4, pp.428–430.

Jöckel, H. (1997) 'Praktische Erfahrungen mit der Radontherapie'. In: H.G. Pratzel and P. Deetjen (Eds.), *Radon in der Kurortmedizin*, pp.84–91, Geretsried: ISMH.

Kondo, S. (1993) 'Health surveys of populations exposed to low level radiation', in: *Health Effects of Low-Level Radiation,* Osaka, Japan: Kinki University Press.

Lubin, J., Boice, J., Edling, C., Hornung, R., Howe, G., Kunz, E., Kusiak, A., Morrison, H., Radford, E., Samet, J., Timarche, M., Woodward, A., Xiang, Y. and Pierce, D. (1994) 'Radon and lung cancer risk: a joint analysis of 11 underground miner studies', US National Institutes of Health, NIH Publication No. 94-3644, Washington, DC.

Mifune, M., Sopbue, T., Arimoto, H., Komoto, Y., Kondo, S. and Tanooka, H. (1992) 'Cancer mortality survey in a spa area (Misasa, Japan) with a high radon background', *Jpn. J. Cancer Res.,* Vol. 83, pp.1–5.

Norkin, C.C. and White, D.J. (2003) *Measurement of Joint Motion: A Guide to Goniometry*, Philadelphia: F.A. Davis Company.

Pfaller, W. (1979) 'Subzelluläre veränderungen der nebennierenrinde nach inhalation von 222-Rn', *Z. Angew Bäder-u Klimaheilk*, Vol. 26, pp.384–390.

Pratzel, H.G. and Artmann, C. (1990) 'Das immunorgan haut im rahmen der balneologie', *Z Phys Med Baln Med Klimatol,* Vol. 19, pp.325–321.

Yamaoka, K., Mitsunobu, F., Hanamoto, K., Shibuya, K., Mori, S., Tanizaki, Y. and Sugita, K. (2004) 'Biochemical comparisons between radon effects and thermal effects on humans in radon hot spring therapy', *J. Radiat. Res.,* Vol. 45, pp.83–88.

Yamaoka, K., Mitsunobu, F., Kojima, S., Shibakura, M., Kataoka, T., Hanamoto, K. and Tanizaki, Y. (2005) 'The elevation of p53 protein level and SOD activity in the resident blood of the Misasa radon hot spring district', *J. Radiat. Res.,* Vol. 46, pp.21–24.