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Effects of Wearable Near-Infrared Rays on Knee Pain in Korean Elderly Adults

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Abstract

To investigate the effects of wearable near-infrared ray-emitting knee pads on knee pain among elderly adults in Korea. Randomized controlled trial evaluating the effects of near-infrared rays (NIR) on knee pain in Korean elderly adults. Five community-based research facilities (two welfare centers, a senior citizen center, and two churches). Forty-seven participants aged 65 years and older who had experienced knee pain. The experimental group (n = 25) wore NIR-emitting knee pads for one month at nighttime while sleeping. The control group (n = 22) wore knee pads without NIR. Demographic characteristics, intensity and duration of knee pain, amount of analgesic medication used, range of motion, gait speed, and health-related quality of life were collected using questionnaires. The experimental group showed decreased intensity ($t = -6.17$, $p < 0.001$) and duration ($t = -3.34$, $p = 0.002$) of knee pain and reduced analgesic use ($t = -2.30$, $p = 0.026$) compared to the control group. NIR may be an effective non-pharmacological option for relieving knee pain in elderly adults.

Keywords : Elderly, Knee, Near-infrared, Pain

1. Introduction

Pain is one of the most common symptoms experienced by older adults[1,2]. In older Korean adults, the most common site for pain is the knee[3]. There are many potential causes of knee pain, including disease, aging, weight, and/or physical demands at work[4,5]. When knee pain interferes with daily life, it can cause serious psychological distress and economic loss. As individuals get older, they tend to experience increased pain intensity[1,5]. Previous studies have identified several limitations in daily activities associated with knee pain among older adults, such as discomfort when walking and difficulty sitting and standing[6]. Thus, interventions to relieve knee pain are needed.

Patients with knee pain typically receive treatment for each condition separately based on the relevant clinical guidelines. Despite various treatment options, patients still report significant pain and limitations in daily activities. When knee pain is diagnosed, patients are typically prescribed medication to manage the pain. However, many Korean elderly adults report dissatisfaction with their medication due to it not providing adequate pain relief[7,8]. These results imply that the current interventions for pain management need improvement. Alternate pain management strategies are particularly necessary among community-dwelling elderly adults who do not receive treatment in hospitals and have difficulty finding appropriate pain relief methods.

Beyond medication or surgery, various non-pharmacological methods to relieve pain have been explored, including exercise, acupuncture, mindfulness, and bee venom acupuncture[9-12]. However, each method has its shortcomings. For example, individuals who are restricted in movement due to pain may have difficulty participating in exercise[13]. Invasive treatments such as acupuncture may not be appropriate for those who fear pain. Therefore, future research should explore alternate intervention methods for relieving knee pain that overcome these shortcomings.

Research on the utilization of near-infrared rays (NIR) has attracted growing attention[14]. Infrared rays (IR) are part of the light wavelength spectrum and are

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classified as far-infrared rays (FIR), mid-infrared rays (MIR), and near-infrared rays (NIR). To date, the majority of research and development has focused on FIR, which has been shown to induce various biological effects, including raising body temperatures[15,16]. In the clinical setting, FIR have been used in ophthalmology and obstetrics for targeted irradiation treatments. NIR have been shown to penetrate deeper into tissues and cause less damage to the body than FIR[17,18]. In one study, NIR were found to cause less severe destruction of surrounding tissues from heat[18]. These findings suggest that NIR may be suitable for biomedical application. Further research is needed to develop and evaluate an intervention method using NIR technologies that aims to relieve the pain frequently experienced by elderly adults. NIR have been applied in palliative medical approaches for pain reduction and impairment of wound healing in other countries[19]. Although NIR have been explored for cell imaging, cancer therapy, and applications for absorbing organic photovoltaics[18], to our knowledge, no clinical studies on NIR use for pain management have been conducted among the Korean population.

Given the limitations in movement and daily activities associated with knee pain, this study assessed the effect of NIR on participant's range of motion (ROM). Since limitations in knee ROM may be associated with a reduced ability to walk, the participants' gait speed was measured. In addition, chronic pain has been shown to reduce quality of life[6,20]. Previous studies have shown that pain due to aging and chronic conditions has an overall effect on an individual's quality of life[3]. As a result, it has been suggested that future research in pain include health-related quality of life assessments[21]. Therefore, this study aimed to investigate the effects of NIR on the intensity and duration of knee pain, analgesic use, range of motion, gait speed, and health-related quality of life among community-dwelling elderly adults in Korea.

2. Methods

2.1. Study design and Participants

A cluster randomized controlled trial design was used to evaluate the clinical effects of NIR on knee pain among Korean elderly adults. A total of 47 elderly adults aged 65 years and older were included in this study. The inclusion criteria were knee pain level of $\geq$ 5 on the visual analogue scale (VAS) in the previous month and no contraindications for infrared ray use. Participants who were diagnosed with degenerative arthritis and experience continuous knee pain were included, even if taking arthritis medicine. Participants who had undergone knee arthroplasty were excluded, as the procedure aims to reduce pain and difficulty in daily activities[22]. In addition, patients who were currently hospitalized due to knee pain, those regularly receiving outpatient treatments, those with a history of mental illness, those currently taking psychiatric medication, and those diagnosed with rheumatoid arthritis or gouty arthritis were excluded. The number of participants were calculated using the G*power 3.12 program. For statistical power analysis, the following parameters were used: *t*-test formula; effect size, $d = 0.80$; number of groups, n = 2; significance level, $p \leq 0.05$; and power required, $[1-\beta] = 0.80$. The required sample size was 21 participants per group. A total of 60 elderly adults were recruited to the experimental (n = 30) or control group (n = 30). Participants were excluded if they did not wear the knee pad continuously (n = 13), and the remaining 47 participants were included in the analysis (experimental group, 25 participants; control group, 22 participants). To maintain separation between the experimental and control groups, the participants in District A were randomly assigned the experimental intervention and those in District B were assigned the control intervention.

2.2. Measures

The visual analogue scale (VAS) was used to measure the intensity of knee pain. The VAS measures pain by having participants indicate the level of pain along a 10-centimeter straight line. The participants were asked to place a mark on the line to indicate their average level of the knee pain intensity over the last month, ranging from "no pain at all" (score of 0) to "the severest pain" (score of 10). The higher the score, the more severe the pain. The number of days that participants experienced knee pain per week was collected to assess the duration of knee pain.

The frequency of pain medication use per week for knee pain relief was measured. In this study, pain killers were defined as any oral medication taken by the participants to alleviate knee pain, in addition to arthritis

medication.

Knee joint ROM was assessed by measuring the knee flexion angle using a goniometer (KASCO Stainless, Japan). While sitting comfortably on the floor, participants were instructed to flex their knee joint, and the angle between the femur and the tibia was measured. The average of two measurements was used. A smaller flexion angle indicated better functioning of the knee joint[22]. Gait speed was assessed by measuring the time required to walk 10 meters at a normal speed. Participants were instructed to walk at "normal speed" starting at a start signal, and the average time of two measurements was used for the analysis. In the gait speed assessment, a higher average time indicated reduced knee function.

The health-related quality of life (HRQOL) of the participants was assessed using the Korean version of the SmithKline Beecham Quality of Life Scale (SBQOL)[23,24]. This tool consists of 23 items and assesses five components of quality of life: competence (seven items), psychological well-being (four items), stability (six items), physical well-being (four items), and activity (two items). Participants scored each item on a range from 1 to 10, resulting in total score ranging from 23 to 230. A higher score indicated a higher HRQOL. The internal consistency for the SBQOL-K was assessed using Cronbach's α and was calculated to be 0.85 in this study, similar to a previous study by Yoon *et al*. that reported a Cronbach's α of 0.89[24].

2.3. Data Collection and Ethical Consideration

Data were collected from September to This study was approved by the Institutional Review Board (IRB) of C University, South Korea (2-1041055-AB-N-01-2016-0037). Participants were recruited from welfare centers, a senior citizen center, and churches in G city, South Korea between April and August 2017. Elderly adults who were interested in participating were provided information about the study. The participants were informed that their data would be deidentified and used only for the purposes of this study. All participants provided written informed consent prior to randomization. All study participants were given a souvenir as a token of appreciation.

At baseline, all participants completed a demographics questionnaire and completed assessments relating to the study outcomes (intensity and duration of knee pain, analgesics use, ROM, gait speed, and HRQOL). The experimental group was provided a prototype NIR-irradiating knee pad to be worn on the affected knee joint. Participants experiencing pain on both knees were instructed to wear the knee pad on the knee with the more severe pain. The prototype NIR knee pad is a cloth knee pad with embedded NIR emitting diodes that heat the pad to 104°F (40°C). The diodes emit NIR wavelengths between 700-1,000 nm, producing heat that is harmless to the human body[25]. The NIR knee pad is connected to a wearable battery. The participants were instructed to wear the knee pad wrapped in a towel to replicate a previous study that used a hot pack wrapped with a towel[26]. The intervention duration was set to 1 month based on previous studies that used 4-week interventions for knee pain relief[27,28]. Participants wore the knee pad at night while sleeping. Nighttime was selected in order to ensure continuous wear of the knee pad over several hours. The participants were asked to wear the knee pad if they got up at night (i.e., to go to the bathroom or kitchen). The participants were instructed to continue normal daily activities and were permitted to take analgesics in addition to their arthritis medication when needed.

Participants in the control group were provided a knee pad that was similar in appearance to the experimental knee pad but did not irradiate NIR. All other study procedures were consistent between the experimental and control group. Following the 1-month study period, all participants completed a post-test questionnaire.

2.4. Data Analysis

All data analysis was completed using SPSS version 23.0. Chi-square tests, Fisher's exact tests, and independent *t*-tests were performed to compare demographic characteristics and pre-test variables between the two groups. An independent *t*-test was used to compare the differences in pre- and post-test scores between the two groups. P-values of ≤ 0.05 were considered statistically significant.

3. Results

The demographic characteristics and baseline scores for the experimental and control groups are summarized in Tables 1 and 2. No significant differences were

Table 1. Homogeneity test of general characteristics for participants (N=47)

Characteristics	Categories	Experimental group (n=25)	Control group (n=22)	t or x^2	p
		n(%) or M±SD	n(%) or M±SD		
Gender*	Male Female	4(16.0) 21(84.0)	4(18.2) 18(81.8)	-	1.000
Age		76.80±6.60	78.14±6.91	-0.68	.502
Marital status**	Married Beverage	3(12.0) 22(88.0)	0(0.0) 22(100.0)	-	.237
Education level	No education Elementary school	8(32.0) 17(68.0)	8(36.4) 14(63.6)	0.10	.753
Job*	Yes No	3(12.0) 22(88.0)	0(0.0) 22(100.0)	-	.237
Economic status	Not enough Fair	16(64.0) 9(36.0)	15(68.2) 7(31.8)	0.09	1.000
Health status*	Unhealthy Fair	21(84.0) 4(16.0)	19(86.4) 3(13.6)	-	1.000
Disease*	Yes No	21(84.0) 4(16.0)	21(95.5) 1(4.5)	-	.352
Side of knee pain	Left side Light side Both	9(36.0) 3(12.0) 13(52.0)	5(22.7) 8(36.4) 9(40.9)	3.97	.138
Osteoarthritis	Yes No	18(72.0) 7(28.0)	18(81.8) 4(18.2)	0.63	.428
Taking medication of osteoarthritis	Yes No	17(58.0) 8(32.0)	17(77.3) 5(22.7)	0.50	.478
Use of assistant device*	Yes No	21(84.0) 4(16.0)	18(81.8) 4(18.2)	-	1.000

*Fisher's exact test

Table 2. Homogeneity test of pre-test dependent variables (N=47)

Variables	Experimental group (n=25)	Control group (n=22)	t	p
	M±SD	M±SD		
The intensity of knee pain	7.24±1.48	6.77±1.02	1.27	.210
The duration of knee/week	5.84±1.84	5.36±1.89	0.87	.387
The amount of taking analgesics	2.52±2.00	2.30±2.60	0.33	.740
ROM of knee joint	53.40±32.87	40.23±20.67	1.62	.113
Gait speed	25.76±10.65	23.91±7.57	0.68	.501
HRQOL	117.48±23.02	117.64±20.29	-0.03	.981

ROM=Range of motion; HRQOL=Health related quality of life

observed in the baseline characteristics or assessment scores between the two groups.

At study completion, participants in the intervention group had a statistically significant decrease in their reported intensity and duration of knee pain compared to the control group, as well as reduced analgesics use. The VAS pain scores in the experimental group decreased from 7.24 to 3.72, whereas the VAS scores in the control group decreased from 6.77 to 5.82. The change in VAS scores indicated a significant difference in the knee pain

Table 3. Changes in pain of irradiation of NIR (N=47)

Variables	Group	Pre-test	Post-test	Mean difference	t	p
		M±SD	M±SD	M±SD		
The intensity of knee pain	Exp.	7.24±1.48	3.72±1.79	-3.52±1.61	-6.17	<.001
	Con.	6.77±1.02	5.82±1.65	-0.95±1.17		
The duration of knee pain/week	Exp.	5.84±1.84	4.04±1.93	-1.80±1.35	-3.34	.002
	Con.	5.36±1.89	4.91±2.04	-0.45±1.41		
The amount of taking analgesics	Exp.	2.52±2.00	0.88±0.97	-1.64±1.32	-2.30	.026
	Con.	2.30±2.60	1.86±2.62	-0.43±2.22		
ROM of knee joint	Exp.	53.40±32.87	52.84±34.00	-0.56±3.66	1.52	.135
	Con.	40.23±20.67	38.05±19.14	-2.18±3.62		
Gait speed	Exp.	25.76±10.65	25.56±11.13	-0.20±2.25	1.07	.289
	Con.	23.91±7.57	23.00±7.46	-0.91±2.27		
HRQOL	Exp.	117.48±23.02	123.00±26.59	5.52±15.20	0.20	.846
	Con.	117.64±20.29	122.18±17.83	4.55±18.93		

NIR=Near-infrared ray; Exp.=Experimental group; Cont.=Control group; ROM=Range of motion; HRQOL=Health related quality of life

intensity between two groups (t = –6.17, p < 0.001).

In the experimental group, the duration of knee pain decreased from 5.84 days per week at baseline to 4.04 days at follow-up, whereas little change in the duration of knee pain was observed in the control group (from 5.36 to 4.91 days). The duration of knee pain was significantly reduced in the experimental group compared to the control (t = –3.34, p = 0.002).

Pain medication use was significantly reduced among participants in the intervention group (from 2.52 to 0.88) compared to participants in the control group (from 2.30 to 1.86) (t = –2.30, p = 0.026) (Table 3).

4. Discussion

After wearing the NIR-emitting knee pad for 1 month, the experimental group had significantly reduced intensity and duration of knee pain. In addition, participants in this group showed reduced painkiller use. These results indicate that NIR may be a suitable alternative to FIR-emitting plaster treatment, which has been shown to relieve pain in patients with knee osteoarthritis[28]. In the present study, the experimental group experienced a significant decrease in knee pain intensity, with scores decreasing from 7.24 to 3.72. In addition, the experimental group experienced knee pain only approximately 4 days of knee pain at follow-up, compared to nearly 6 days per week at baseline. To date, only FIR has been used in clinical settings for pain relief. During FIR treatment, patients are irradiated with FIR for a short period of time, typically less than 30 minutes, and the procedure requires patients to limit their movement while receiving the FIR radiation. In the present study, the participants were exposed to NIR for an average of 6 hours per day, and the participants were able to maintain normal daily activities while wearing the knee pad. The results suggest that NIR-irradiating knee pads may be an effective new method for continuous pain relief. In addition, devices using FIR are generally larger in size and require more power (30 to 100 Watts). Therefore, the limitations of FIR devices may be addressed by using NIR, which offers greater convenience and safety.

Reducing painkiller use is desirable from both economic and health perspectives, as analgesic use can involve the purchase and use of inappropriate over-the counter (OTC) drugs. One previous study showed that the most common condition leading to OTC medication usage was pain such as headaches, arthralgia, and toothaches[29]. Therefore, non-pharmacological interventions that relieve pain may offer the additional benefits of reduced painkiller use and reduced spending on OTC drugs. Moreover, long-term use of analgesics for pain relief can cause adverse health effects, such as gastrointestinal disturbances[30], whereas an NIR-based intervention may provide pain relief without these side effects. Further research is necessary to evaluate the effects of continuous NIR irradiation on long-term out-

comes of pain.

There was no significant change in gait speed associated with wearing the NIR knee pad. However, participants in the experimental group reported that the knee felt less stiff and that walking became easier. Generally, for persons experiencing minor joint pain, some steady movements of the joint are recommended. Moving the joint increases the local temperature, allows the joint to become more flexible, and strengthens the muscles around the joint, which all contribute to pain reduction. Future research should consider assessing other activities such as climbing stairs in addition to normal gait speed when the knee pain is alleviated.

Participants who received the intervention experienced benefits, including the reduce pain and analgesic use, but did not report improved health-related quality of life. This no effect on QOL differs from the findings of previous studies. Research by Li et al. that evaluated the effects of FIR reported improvements in QOL[16]. To date, no studies have investigated the psychological effects of NIR. However, if pain is reduced, psychological HRQOL is expected to improve. These study results may be explained the study duration of one month, which did not provide sufficient time to observe changes in HRQOL. Therefore, psychological factors related to pain should be evaluated over a longer term in future studies. Lastly, this study was limited in terms of generalization as all participants were recruited from one city in Korea. Future research should explore the use of NIR in other populations.

5. Conclusion

This study found that an NIR-irradiating wearable knee pad provided significant therapeutic benefits in community-dwelling Korean elderly adults experiencing knee pain. The intervention group showed decreased intensity and duration of knee pain and reduced painkiller use than the control group. No serious or significant adverse effects were reported among those wearing the NIR-emitting knee pad. These results suggest that a wearable NIR device may be an effective intervention for pain relief in elderly adults experiencing knee pain. Further research is needed to validate these findings and to evaluate the effects of applying NIR to other regions of the body that are experiencing pain.

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