Received: 9 December 2023 | Revised: 9 August 2024 | Accepted: 12 August 2024

DOI: 10.1002/ccr3.9355

CASE REPORT

Clinical Case Reports Open Access WILEY

Effects of an arm ergometer for a patient with knee osteoarthritis and central sensitization: A case report

Hironobu Uzawa[1] | **Toshiro Otani**[2] | **Kenichi Morii**[3] | **Takashi Asakawa**[3] | **Hiroto Furuyama**[4] | **Yusuke Nishida**[1]

[1]Department of Physical Therapy, School of Health Sciences at Narita, International University of Health and Welfare, Narita, Japan

[2]Department of Orthopedic Surgery, International University of Health and Welfare (IUHW) Ichikawa Hospital, Ichikawa, Japan

[3]Department of Rehabilitation, International University of Health and Welfare (IUHW) Ichikawa Hospital, Ichikawa, Japan

[4]Department of Rehabilitation, International University of Health and Welfare (IUHW) Narita Hospital, Narita, Japan

Correspondence
Hironobu Uzawa, Department of Physical Therapy, School of Health Sciences at Narita, International University of Health and Welfare, 4-3, Kozunomori, Narita, Chiba 286-8686, Japan.
Email: h.uzawa@iuhw.ac.jp

Funding information
Japan Society for the Promotion of Science, Grant/Award Number: 21K19733

Key Clinical Message

Aerobic exercise may be an effective treatment for knee osteoarthritis and central sensitization, but no interventional studies have examined its effects. In this study, the patient showed improvement in central sensitization, pain, and autonomic nervous system activity after aerobic exercise using an arm ergometer.

KEYWORDS

aerobic exercise, autonomic nervous system, central nervous system sensitization, knee, osteoarthritis

1 | INTRODUCTION

Knee osteoarthritis (OA) is prevalent in people aged 60 years and older.[1] Patients with knee OA tend to have concomitant central sensitization, which is the "increased responsiveness of nociceptive neurons in the central nervous system to their normal or subthreshold afferent input."[2] Approximately 36.0%–53.2% of patients with knee OA have central sensitization.[3,4] Because patients with both conditions show higher pain intensity and greater functional limitations than those with knee OA alone,[5] optimal management is required.

Aerobic exercise may be effective in the treatment of knee OA[6] and central sensitization.[7] It could improve autonomic nervous system activity in patients with central sensitization.[8] Central sensitization is associated with the descending pain modulatory system,[9] which is partially controlled by the autonomic nervous system.[10] Furthermore, descending pain modulation and autonomic nervous systems share the same neural pathways which include the rostral ventromedial medulla and periaqueductal gray.[11] As aerobic exercise benefits autonomic nervous system activity,[12] it may be effective in the treatment of central sensitization; it may alleviate knee pain and central sensitization. However, to our knowledge, no interventional studies have examined the effect of aerobic exercise on patients with OA and central sensitization.

This case study aimed to examine the effects of aerobic exercise using an arm ergometer on central sensitization, pain, and autonomic nervous system activity in a patient with knee OA and central sensitization. The arm ergometer allowed the patient to perform exercises without

loading her knee joints. Because the arm ergometer is more effective than a leg ergometer or treadmill in patients with knee OA,[13] it was suitable for use in this study.

2 | METHODS

2.1 | Ethical considerations and guidelines

The study procedures complied with the tenets of the Declaration of Helsinki and the study protocol was approved by the Institutional Review Board of the International University of Health and Welfare, Narita, Chiba, Japan (approval number: 22-Im-011). This study was registered in the UMIN Clinical Trials Registry on September 1, 2022 (registry ID: UMIN000048356). The eligibility criteria are described on the UMIN Clinical Trials website. The patient was screened for eligibility, and written informed consent was obtained before commencement of the study.

This case study followed the Consensus-based Clinical Case Reporting Guideline Development guidelines.[14] Figure 1 shows the time schedule for this study.

2.2 | Patient information

A 60-year-old Japanese woman presented at our department. She was 155 cm tall, weighed 55.0 kg, and had a body mass index of 22.9 kg/m^2. She worked daily as a housekeeper and 4 days/week as a gymnasium clerk or piano coach.

She was diagnosed with grade 1 OA according to the Kallgren–Lawrence classification system.[15] Knee pain had started in the left joint 6 years prior to presentation, and in the right 3 years prior. At presentation, she complained of more severe pain in the right knee than in the left, with a maximum numerical pain rating scale score of eight while walking. The range of motion in both knee joints was 140° in flexion and 0° in extension without pain. Muscle strength in knee extension measured with a handheld dynamometer was 38.3/43.2 kg (right/left). Orthopedic ligament tests of the knee joint indicated no positive signs of flexibility or pain. One year earlier, she had undergone physiotherapy at an orthopedic clinic for 3 months, with no alleviation of knee pain. She had no history of surgery, and the only comorbidity was hypertension without medication intake. The current medications were nonsteroidal anti-inflammatory drugs (celecoxib 100 mg), which she had been taking twice per day for 1 year, without improvement in her knee pain.

2.3 | Therapeutic interventions

The interventions were performed 12 times over 3 months from February 20 (Day 1) to May 27 (Day 12), 2023 (Figure 1). We used a TERASUERUGO® arm ergometer (TE4-70, Showa Denki Co., Ltd., Osaka, Japan). The load was set to 60%–75% of the predicted maximum heart rate (220 − age),[16] and we used 20 W in this case. The patient performed one session on each day with the arm ergometer for 10–12 min and subsequently rested for 3 min.

Furthermore, several home exercise programs were recommended to her, including resistance training and stretching (knee extension and flexion, and trunk rotation and extension). Adherence to home exercise was assessed weekly by Hironobu Uzawa.

2.4 | Outcome measures

Pre- and post-intervention assessments were performed on February 2 and June 10, 2023, respectively (Figure 1). We

	Study Period		
	Baseline	**Interventions (day 1-12)**	**Post-intervention**
Timepoint	**2 February**	**20 February to 27 May**	**10 June**
Enrolment:			
Eligibility screen and informed consent	X		
Interventions:			
Arm ergometer with self-exercise		X	
Assessments:			
Basic characteristics	X		
Conditioned pain modulation	X		X
Numerical rating scale for knee pain	X		X
Questionnaires	X		X
Autonomic nervous system activities		X	

FIGURE 1 Study schedule. This figure shows the time points used in the case study. "X" refers to the items (e.g., basic characteristics) assessed.

used conditioned pain modulation (CPM) and the Central Sensitization Inventory (CSI) to assess central sensitization. In CPM, she immersed her right hand in 8–12°C cold water for three 45-s immersions in three 15-s intervals.[17] The pressure pain threshold (PPT) was measured using a Wagner FPX-25 (Wagner Instruments, Greenwich, CT) on her left upper trapezius before and after cold-water immersion.[18] The difference in the PPT before and after immersion was calculated, and a negative number indicated central sensitization.[19] The CSI is a questionnaire used to screen for central sensitization, which is positive if the score exceeds 40.[20]

The R–R intervals were measured using an arm ergometer and a wearable heart rate sensor (WHS-1, Union Tool Co. Ltd., Tokyo, Japan) at low and high frequencies (LF and HF, respectively) and analyzed using an RRI Analyzer 2 (Union Tool Co. Ltd.). LF/HF indicates sympathetic nervous system activity, and the HF normalized unit (HF_{nu}) was calculated using the following formula: HF/(HF + LF), indicating parasympathetic nervous system activity.[21]

Pain intensity was evaluated on a numerical rating scale for average and maximum knee pain while walking. The area of pain was described using the Michigan Body Map.[22]

Several questionnaires (the PainDETECT,[23] Pain Catastrophizing Scale,[24] International Physical Activity Questionnaire,[25] Hospital Anxiety and Depression Scale,[26] Pittsburgh Sleep Quality Index,[27] Checklist for Individual Strength,[28] and Western Ontario and McMaster Universities Osteoarthritis Index[29]) were administered.

2.5 | Diagnostic assessment

The pre-assessment values were a CPM score of −0.08 and CSI score of 42. Therefore, we evaluated the patient for central sensitization.

3 | RESULTS

The CPM score improved from −0.08 to 0.70. The CSI score improved from 42 to 39. The numerical rating scale score improved from two to one for average pain, and from eight to two for maximum pain while walking. The pain area also narrowed (Figure 2). All questionnaires, except the International Physical Activity Questionnaire and the Pittsburgh Sleep Quality Index, showed improvement. Table 1 presents the results of all assessments. No

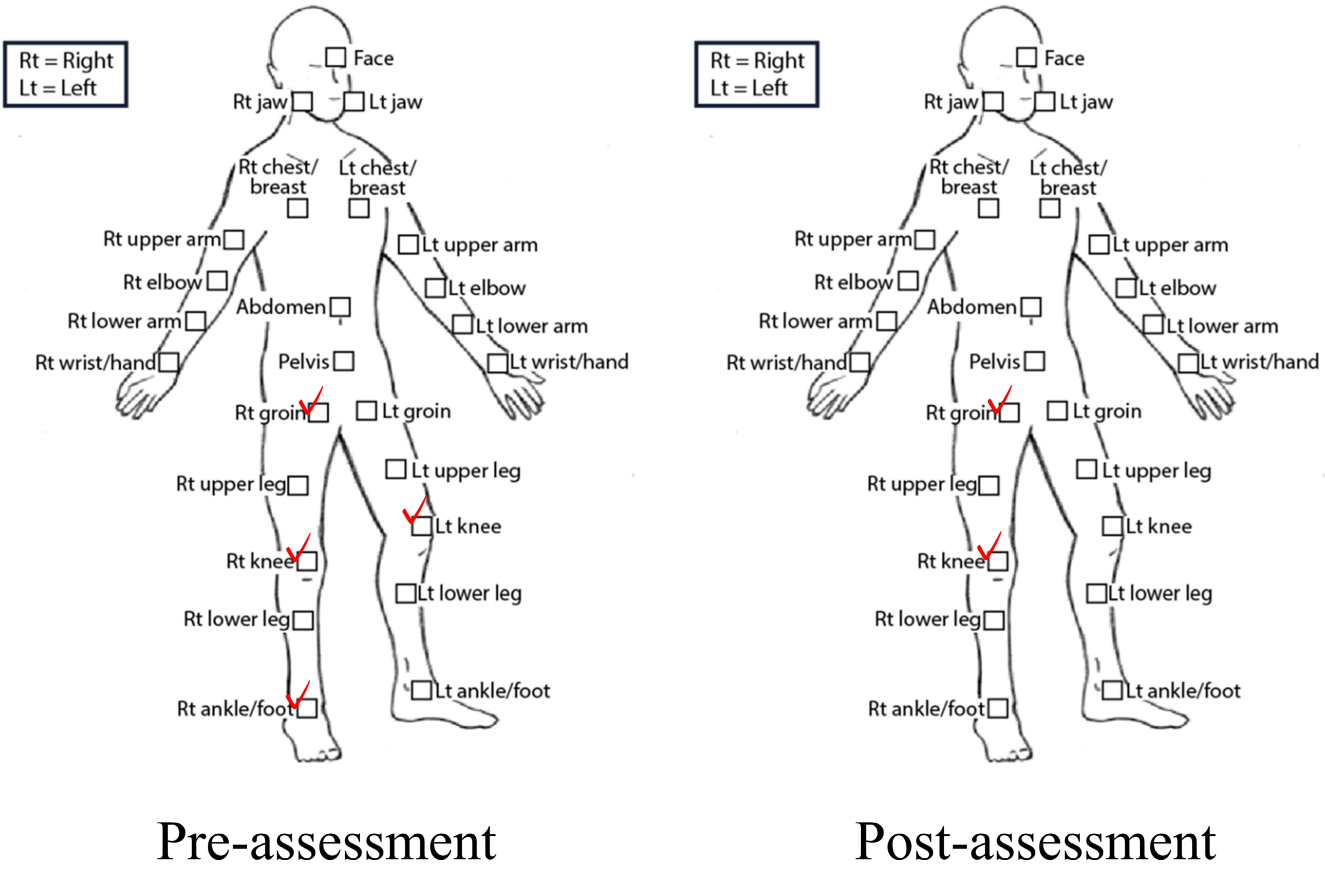

FIGURE 2 Pain diagram pre- and post-interventions. This study used the Michigan Body Map to determine the pain area. A tick indicates that the patient had pre- and post-assessments for pain.

TABLE 1 Results of assessments pre- and post-intervention.

Assessments	Pre-intervention	Post-intervention
Conditioned pain modulation	−0.08	0.7
Central sensitization inventory	42	39
Pain intensity (average)	2	1
Pain intensity (maximum)	8	2
PainDETECT	15	12
Pain Catastrophizing Scale	41	32
International Physical Activity Questionnaire	6.6	4.4
Hospital Anxiety and Depression Scale (Anxiety)	8	6
Hospital Anxiety and Depression Scale (Depression)	5	2
Pittsburgh Sleep Quality Index	7	9
Checklist for Individual Strength	74	54
Western Ontario and McMaster Universities Osteoarthritis Index	21	20

Note: This table presents the results of the assessments. Conditioned pain modulation is a test for central sensitization. The cutoff is 0, and a negative value means the patient has central sensitization. The Central Sensitization Inventory is also a questionnaire on central sensitization. A score above 40 indicates central sensitization. Pain intensity was measured on a numerical rating scale. Other outcomes were questionnaire scores, with higher scores indicating more severe symptoms and functional limitations.

adverse events such as deteriorating knee pain occurred. The patient stated "the arm ergometer was tiring, but effective in alleviating pain."

The average LF/HF decreased from 2.59 on Day 1 to 0.76 on Day 12 with arm ergometer use. In the recovery phase, the average LF/HF ratio decreased from 1.45 to 0.51. The average HF_{nu} increased from 0.29 to 0.58 with arm ergometer use, and the HF_{nu} increased from 0.44 to 0.66 during recovery (Table 2).

TABLE 2 Autonomic nervous system activity during and after arm ergometer use.

Assessments	Day 1 (20 February)	Day 12 (27 May)
Average LF/HF during arm ergometer	2.59	0.76
Average LF/HF during recovery	1.45	0.51
Average HF_{nu} during arm ergometer	0.29	0.58
Average HF_{nu} during recovery	0.44	0.66

Note: This table presents the average low and high frequencies (sympathetic nervous system activities) and high-frequency normalized units (parasympathetic nervous system activities) during exercise and recovery. A higher value indicates greater activity.

4 | DISCUSSION

The aim of this case study was to examine the effects of aerobic exercise using an arm ergometer on central sensitization, pain, and autonomic nervous system activity in a patient with knee OA and central sensitization. After the intervention, the patient showed improvement in these conditions.

Before the intervention, the patient had a CPM score of −0.08 and CSI score of 42, indicating the presence of central sensitization.[19,20] Furthermore, she had a relatively high LF/HF at 2.59 during exercise on Day 1, as the LF/HF of healthy people is approximately 1.48 ± 1.20.[30] After the intervention, her CPM score improved to 0.70, and her CSI score to 39, indicating the absence of central sensitization; reduced sympathetic nervous system activity during the exercise was indicated by a LF/HF of 0.76 on Day 12. We believe that the aerobic exercise using the arm ergometer improved these conditions because it has previously been reported to alleviate autonomic nervous system activity and central sensitization.[8] The underlying reason may be that central sensitization is thought to be a dysfunction of the descending pain modulatory system,[9] and this system and the autonomic nervous system share the same neural pathways, in the rostral ventromedial medulla and periaqueductal gray.[11] In fact, some patients with chronic musculoskeletal pain and central sensitization experience autonomic dysfunction during rest and exercise.[31,32] Thus, as aerobic exercise alleviates autonomic nervous system activity,[12] it may also have been effective in alleviating the patient's central sensitization.

In addition, her pain level decreased from two to one for average pain, and from eight to two for maximum pain while walking, and the pain was more localized. The symptoms of central sensitization are segmental and extra-segmental spreading sensitization; therefore, the lower pain intensity and more localized pain could have been brought about by an improvement in central sensitization.[9] Furthermore, the patient showed improvements

in pain-related symptoms, such as pain catastrophizing and fatigue. These improvements could also have resulted from the alleviated central sensitization associated with pain-related symptoms.[33,34]

As this study focuses on one patient, it is important to acknowledge the potential biases that might have influenced the effects of the intervention. First, the patient was taking celecoxib, which might have impacted the results. However, since the medication had been taken for a year without any reduction in knee pain, we believe it is unlikely to have influenced her condition during the study. Second, our patient engaged in aerobic exercise only once per week. While a systematic review[35] on the effects of aerobic exercise in patients with non-specific neck pain reported that the participants performed aerobic exercise at least twice per week, our protocol was based on two factors: The primary factor was the patient's inability to visit the hospital more than once a week due to work commitments. This limitation was beyond our control. The secondary factor was that a few observational studies have shown changes in autonomic activity after a single session of aerobic exercise per week. For instance, one observational study[30] found that a single bout of 75% predicted heart rate max aerobic exercise caused changes in HF and LF/HF. Our patient performed aerobic exercise with a load of 60%–75%, and we hypothesize that even this frequency could lead to improvements in the patient's condition due to the correlation between autonomic activity and central sensitization.[9,11] Third, the patient also performed self-exercise, such as resistance training and stretching, which might have contributed to her improvement. However, a few studies have reported that resistance exercise and stretching do not improve autonomic activity.[36,37] Given that our patient showed improvement in autonomic activity, which we hypothesize may have alleviated central sensitization, knee pain, and pain-related outcomes, we suggest that the aerobic exercise using the arm ergometer may have played a significant role in her improvement.

AUTHOR CONTRIBUTIONS

Hironobu Uzawa: Conceptualization; data curation; formal analysis; funding acquisition; investigation; methodology; visualization; writing – original draft. **Toshiro Otani:** Methodology; resources; supervision. **Kenichi Morii:** Methodology; resources. **Takashi Asakawa:** Methodology; resources. **Hiroto Furuyama:** Writing – review and editing. **Yusuke Nishida:** Methodology; supervision.

ACKNOWLEDGMENTS

This case report was funded by the JSPS Grants-in-Aid for Challenging Research, Explorator (21 K19733). We thank the rehabilitation staff and clerical workers at the International University of Health and Welfare Ichikawa hospital for assisting with the measurements and interventions in this case. We also thank Editage (www.editage.com) for English language editing.

FUNDING INFORMATION

This case report was funded by the JSPS Grants-in-Aid for Challenging Research, Explorator (21 K19733).

CONFLICT OF INTEREST STATEMENT

The authors declare no conflict of interest and the funders had no role in any of the procedures in this report.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

ETHICS STATEMENT

The study procedures complied with the tenets of the Declaration of Helsinki and the study protocol was approved by the Institutional Review Board of the International University of Health and Welfare, Narita, Chiba, Japan (approval number: 22-Im-011).

CONSENT

Written informed consent was obtained from the patient to publish this report in accordance with the journal's patient consent policy.

CLINICAL TRIAL REGISTRATION

This study was registered in the UMIN Clinical Trials Registry on September 1, 2022 (registry ID: UMIN000048356).

PERMISSION TO REPRODUCE MATERIAL FROM OTHER SOURCES

Not applicable for this study.

ORCID

Hironobu Uzawa https://orcid.org/0000-0001-9168-7917

REFERENCES

1. Sharma L. Osteoarthritis of the knee. *N Engl J Med*. 2021;384(1):51-59. doi:10.3389/fpubh.2017.00258
2. International Association for the Study of Pain. *Terminology* . International Association for the Study of Pain website. https://www.iasp-pain.org/resources/terminology/ Published 2021. Accessed 23 November, 2023.
3. Kılıçaslan H, Genç A, Tuncer S. Central sensitization in osteoarthritic knee pain: a cross-sectional study. *Turk J Phys Med Rehabil*. 2023;69(1):89-96. doi:10.5606/tftrd.2023.10470
4. Zolio L, Lim KY, McKenzie JE, et al. Systematic review and meta-analysis of the prevalence of neuropathic-like pain and/

or pain sensitization in people with knee and hip osteoarthritis. *Osteoarthr Cartil*. 2021;29(8):1096-1116. doi:10.1016/j.joca.2021.03.021

5. Goldoni ES, Bittencourt JV, do Espirito Santo LR, et al. Neuropathic-like symptoms and central sensitization related signs and symptoms negatively affect the functional performance of patients with knee osteoarthritis—a cross-sectional study. *Osteoarthr Cartil Open*. 2023;5(2):100358. doi:10.1016/j.ocarto.2023.100358
6. Zeng CY, Zhang ZR, Tang ZM, Hua FZ. Benefits and mechanisms of exercise training for knee osteoarthritis. *Front Physiol*. 2021;12:794062. doi:10.1515/revneuro-2023-0037
7. Basem JI, Haffey PR. Novel therapies for centralized pain: a brief review. *Curr Pain Headache Rep*. 2022;26(11):805-811. doi:10.1007/s11916-022-01085-z
8. Sañudo B, Carrasco L, de Hoyo M, Figueroa A, Saxton JM. Vagal modulation and symptomatology following a 6-month aerobic exercise program for women with fibromyalgia. *Clin Exp Rheumatol*. 2015;33(1 Suppl 88):S41-S45.
9. Arendt-Nielsen L, Morlion B, Perrot S, et al. Assessment and manifestation of central sensitisation across different chronic pain conditions. *Eur J Pain*. 2018;22(2):216-241. doi:10.1002/ejp.1140
10. Rice D, Nijs J, Kosek E, et al. Exercise-induced hypoalgesia in pain-free and chronic pain populations: state of the art and future directions. *J Pain*. 2019;20(11):1249-1266. doi:10.1016/j.jpain.2019.03.005
11. Yao D, Chen Y, Chen G. The role of pain modulation pathway and related brain regions in pain. *Rev Neurosci*. 2023;34(8):899-914. doi:10.1515/revneuro-2023-0037
12. Sánchez-Delgado JC, Jácome-Hortúa AM, de Melo KY, Aguilar BA, Philbois SV, de Souza HCD. Physical exercise effects on cardiovascular autonomic modulation in postmenopausal women-a systematic review and meta-analysis. *Int J Environ Res Public Health*. 2023;20(3):2207. doi:10.3390/ijerph20032207
13. Kabiri S, Halabchi F, Angoorani H, Yekaninejad S. Comparison of three modes of aerobic exercise combined with resistance training on the pain and function of patients with knee osteoarthritis: a randomized controlled trial. *Phys Ther Sport*. 2018;32:22-28. doi:10.1016/j.ptsp.2018.04.001
14. Riley DS, Barber MS, Kienle GS, et al. CARE guidelines for case reports: explanation and elaboration document. *J Clin Epidemiol*. 2017;89:218-235. doi:10.1016/j.jclinepi.2017.04.026
15. Kohn MD, Sassoon AA, Fernando ND. Classifications in brief: Kellgren-Lawrence classification of osteoarthritis. *Clin Orthop Relat Res*. 2016;474(8):1886-1893. doi:10.1007/s11999-016-4732-4
16. King SJ, Wessel J, Bhambhani Y, Sholter D, Maksymowych D. The effects of exercise and education, individually or combined, in women with fibromyalgia. *J Rheumatol*. 2002;29(12):2620-2627.
17. Naugle KM, Ohlman T, Wind B, Miller L. Test-retest instability of temporal summation and conditioned pain modulation measures in older adults. *Pain Med*. 2020;21(11):2863-2876. doi:10.1093/pm/pnaa288
18. Walton DM, Macdermid JC, Nielson W, Teasell RW, Chiasson M, Brown L. Reliability, standard error, and minimum detectable change of clinical pressure pain threshold testing in people with and without acute neck pain. *J Orthop Sports Phys Ther*. 2011;41(9):644-650. doi:10.2519/jospt.2011.3666
19. Ramaswamy S, Wodehouse T. Conditioned pain modulation-a comprehensive review. *Neurophysiol Clin*. 2021;51(3):197-208. doi:10.1016/j.neucli.2020.11.002
20. Mayer TG, Neblett R, Cohen H, et al. The development and psychometric validation of the central sensitization inventory. *Pain Pract*. 2012;12(4):276-285. doi:10.1111/j.1533-2500.2011.00493.x
21. Shaffer F, Ginsberg JP. An overview of heart rate variability metrics and norms. *Front Public Health*. 2017;5(258):1-17. doi:10.3389/fpubh.2017.00258
22. Hassett AL, Pierce J, Goesling J, et al. Initial validation of the electronic form of the Michigan Body Map. *Reg Anesth Pain Med*. 2019;45:101084. doi:10.1136/rapm-2019-101084
23. Matsubayashi Y, Takeshita K, Sumitani M, et al. Validity and reliability of the Japanese version of the painDETECT questionnaire: a multicenter observational study. *PLoS One*. 2013;8(9):e68013. doi:10.1371/journal.pone.0068013
24. Goodin BR, McGuire L, Allshouse M, et al. Associations between catastrophizing and endogenous pain-inhibitory processes: sex differences. *J Pain*. 2009;10(2):180-190. doi:10.1016/j.jpain.2008.08.012
25. Tomioka K, Iwamoto J, Saeki K, Okamoto N. Reliability and validity of the international physical activity questionnaire (IPAQ) in elderly adults: the Fujiwara-kyo study. *J Epidemiol*. 2011;21(6):459-465. doi:10.2188/jea.je20110003
26. Zigmond AS, Snaith RP. The Hospital Anxiety and Depression Scale. *Acta Psychiatr Scand*. 1983;67(6):361-370. doi:10.1111/j.1600-0447.1983.tb09716.x
27. Buysse DJ, Reynolds CF, Monk TH, Berman SR, Kupfer DJ. The Pittsburgh Sleep Quality Index: a new instrument for psychiatric practice and research. *Psychiatry Res*. 1989;28(2):193-213. doi:10.1016/0165-1781(89)90047-4
28. Worm-Smeitink M, Gielissen M, Bloot L, et al. The assessment of fatigue: psychometric qualities and norms for the Checklist Individual Strength. *J Psychosom Res*. 2017;98:40-46. doi:10.1016/j.jpsychores.2017.05.007
29. McConnell S, Kolopack P, Davis AM. The Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC): a review of its utility and measurement properties. *Arthritis Rheum*. 2001;45(5):453-461. doi:10.1002/1529-0131(200110)45:5<453::aid-art365>3.0.co;2-w
30. Oosterwijck JV, Marusic U, Wandele ID, et al. The role of autonomic function in exercise-induced endogenous analgesia: a case-control study in myalgic encephalomyelitis/chronic fatigue syndrome and healthy people. *Pain Physician*. 2017;20(3):E389-E399.
31. Rampazo EP, Rehder-Santos P, Catai AM, Liebano RE. Heart rate variability in adults with chronic musculoskeletal pain: a systematic review. *Pain Pract*. 2023;24:211-230. doi:10.1111/papr.13294
32. Uzawa H, Akiyama K, Furuyama H, Takeuchi S, Nishida Y. Autonomic responses to aerobic and resistance exercise in patients with chronic musculoskeletal pain: a systematic review. *PLoS One*. 2023;18(8):e0290061. doi:10.1371/journal.pone.0290061
33. Koh HS, Choi YH, Park D, Jeong MG. Association between pain catastrophizing and central sensitization among patients with severe knee osteoarthritis awaiting primary total knee arthroplasty. *Orthopedics*. 2022;45(4):197-202. doi:10.3928/01477447-20220401-06
34. Volcheck MM, Graham SM, Fleming KC, Mohabbat AB, Luedtke CA. Central sensitization, chronic pain, and other symptoms: better understanding, better management. *Cleve Clin J Med*. 2023;90(4):245-254. doi:10.3949/ccjm.90a.22019

35. Paraskevopoulos E, Koumantakis GA, Papandreou M. A systematic review of the aerobic exercise program variables for patients with non-specific neck pain: effectiveness and clinical applications. *Dent Health*. 2023;11(3):339. doi:10.3390/healthcare11030339
36. Gavi MB, Vassalo DV, Amaral FT, et al. Strengthening exercises improve symptoms and quality of life but do not change autonomic modulation in fibromyalgia: a randomized clinical trial. *PLoS One*. 2014;9(3):e90767. doi:10.1371/journal.pone.0090767
37. Kingsley JD, McMillan V, Figueroa A. The effects of 12 weeks of resistance exercise training on disease severity and autonomic modulation at rest and after acute leg resistance exercise in women with fibromyalgia. *Arch Phys Med Rehabil*. 2010;91(10):1551-1557. doi:10.1016/j.apmr.2010.07.003

How to cite this article: Uzawa H, Otani T, Morii K, Asakawa T, Furuyama H, Nishida Y. Effects of an arm ergometer for a patient with knee osteoarthritis and central sensitization: A case report. *Clin Case Rep*. 2024;12:e9355. doi:10.1002/ccr3.9355