Investigation of factors influencing low physical activity levels in community-dwelling older adults with chronic pain: a cross-sectional study

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Abstract

Low levels of physical activity in individuals with chronic pain can lead to additional functional impairment and disability. This study aims to investigate the predictors of low physical activity levels in individuals with chronic pain with and to determine the accuracy of the artificial neural network used to analyze these predictors. Community-dwelling older adults with chronic pain (n = 103) were surveyed for their physical activity level and classified into low, moderate, or high physical activity level groups. Other measures that influence physical activity were also taken at the same time. Logistic regression analysis and multilayer perceptron analysis, an artificial neural network, were used for the analysis. Both analyses revealed that history of falls was a predictor of low levels of physical activity in community-dwelling older adults. Multilayer perceptron analysis showed excellent accuracy. Our data emphasize the importance of fall prevention in improving the physical activity level of community-dwelling older adults with chronic pain. We suggest that future cross-sectional studies should compare multiple analysis methods to show results with improved accuracy.

Introduction

Chronic pain (CP) is present in 1.5 billion people worldwide and is a public health problem [1]. CP can cause negative psychological effects and can lead to low activity, depression, and reduced activities of daily living [2, 3]. The reduced physical activity levels of individuals with CP can lead to further functional impairment and disability, so the various exercise programs to increase physical activity has been recommended [4, 5]. Despite the perceived benefits of increasing physical activity levels for CP, the causes of low physical activity levels in individuals with CP are not well understood. Limited research has reported that factors contributing to low physical activity levels in individuals with CP are complex and varied. Qualitative research suggests that a variety of factors, including pain, fatigue, and risks associated with physical activity, influence barriers to physical activity in adults with CP [6]. Kinesiophobia and pain tolerance thresholds also influence low physical activity levels in adults with CP [7, 8]. However, all previous studies have compared CP groups with healthy controls and thus have not compared individuals with CP with different levels of physical activity.

Fundamentally, treating and resolving CP itself is difficult, so the American Society of Anesthesiologists Task Force on Chronic Pain Management and the American Society of Regional Anesthesia and Pain Medicine have identified goals for the treatment of CP. These include pain management, functional capacity, improved physical and mental health, and improved quality of life for patients with CP [9]. The American Society of Regional Anesthesia and Pain Medicine lists goals of treatment for CP as improving pain management, improving functional capacity, improving physical and mental health, and improving quality of life. Deficits in regular physical activity have a variety of negative effects on CP, so research must focus upon groups of patients with CP with low levels of physical activity [10–12]. Research focusing upon groups with low levels of physical activity among patients with CP is therefore required.
This study aims to extract factors that predict low levels of physical activity among community-dwelling elderly people with CP. We used multilayer perceptron (MLP), an artificial neural network (ANN), in extracting the characteristics of low-activity individuals. Prediction and feature importance using ANN is an analysis that has been notably used in COVID-19 research, and in analysis of factors related to severity of illness, including in predicting severity of illness at an early stage [13, 14]. ANN has been applied in classification, prediction, feature selection, and feature importance. We therefore considered that the functions of prediction and feature importance extraction by ANN would be optimal for the purpose of this study. To date, machine learning analysis has not been used in survey research on CP populations, but it could provide a better predictive model. This study seeks to validate the accuracy of using MLP as a model for predicting physical activity levels among community-dwelling older adults with CP, and to compare it with a conventionally used logistic regression model.

**Results**

**Subject characteristics**

Between 2021 and 2022 of the 315 participants who underwent a health check, 103 subjects (mean age, 77.4 ± 5.0 years; males, 24; females, 79), met the inclusion criteria of this study. One subject was excluded because he did not complete the entire study (Fig. 1). According to the International Physical Activity Questionnaire Environmental Module Short Version (IPAQ-SF) (IPAQ-SF) results, the high/medium physical activity level (HMPAL) group consisted of 35 subjects and the low physical activity level (LPAL) group consisted of 67 subjects. The LPAL group had an average daily calorie consumption (ADCC) of 74.0 ± 91.6 kcal, about 10% of the HMPAL group, and the LPAL group more frequently had falls and had a higher body mass index (BMI) than the HMPAL group (Table 1). Interestingly, the subjects in this study did not differ significantly in pain-related outcomes.
Table 1
Characteristics of the subjects

<table>
<thead>
<tr>
<th></th>
<th>Total (n = 102)</th>
<th>LPAL (n = 67)</th>
<th>HMPAL (n = 35)</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>ADCC (kcal)</td>
<td>294.6 ± 1376.0</td>
<td>74.0 ± 91.6</td>
<td>717.0 ± 2308.4</td>
<td></td>
</tr>
<tr>
<td>Age (y)</td>
<td>77.4 ± 5.0</td>
<td>75.6 ± 5.9</td>
<td>76.7 ± 6.1</td>
<td>0.42</td>
</tr>
<tr>
<td>BMI</td>
<td>22.7 ± 3.2</td>
<td>22.1 ± 3.3</td>
<td>21.8 ± 3.0</td>
<td>0.04</td>
</tr>
<tr>
<td>CSI-9</td>
<td>9.6 ± 5.0</td>
<td>9.6 ± 5.0</td>
<td>8.5 ± 5.3</td>
<td>0.07</td>
</tr>
<tr>
<td>TSK-11</td>
<td>20.5 ± 6.1</td>
<td>20.8 ± 6.4</td>
<td>20.0 ± 5.0</td>
<td>0.52</td>
</tr>
<tr>
<td>History of Falls</td>
<td>30</td>
<td>26</td>
<td>4</td>
<td>0.01</td>
</tr>
<tr>
<td>Grip Strength</td>
<td>21.9 ± 5.9</td>
<td>22.3 ± 6.6</td>
<td>23.4 ± 7.2</td>
<td>0.42</td>
</tr>
<tr>
<td>Walking Speed (m/s)</td>
<td>1.27 ± 0.25</td>
<td>1.27 ± 0.25</td>
<td>1.27 ± 0.25</td>
<td>0.88</td>
</tr>
<tr>
<td>AIS</td>
<td>4.8 ± 3.6</td>
<td>5.1 ± 3.6</td>
<td>3.7 ± 3.2</td>
<td>0.07</td>
</tr>
</tbody>
</table>


Factors associated with LPAL group

The logistic regression analysis (LR) results are shown in Table 2. History of falls (OR: 4.35) was identified as a factor associated with LPAL. Similarly, history of falls (OR: 4.61) was identified as a factor associated with LPAL in the LR adjusted for age and gender.

Table 2
Logistic regression analysis identifying the factors associated with the low physical activity level.

<table>
<thead>
<tr>
<th>Independent variables</th>
<th>Crude OR</th>
<th>95% CI</th>
<th>P</th>
<th>aOR</th>
<th>95% CI</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>BMI</td>
<td>1.12</td>
<td>0.97–1.30</td>
<td>0.13</td>
<td>1.12</td>
<td>0.97–1.30</td>
<td>0.13</td>
</tr>
<tr>
<td>History of Falls</td>
<td>4.35</td>
<td>1.35–13.97</td>
<td>0.14</td>
<td>4.61</td>
<td>1.41–15.03</td>
<td>0.01</td>
</tr>
</tbody>
</table>

OR: Odds Ratio, 95% CI: 95% Confidential Interval, BMI: Body Mass Index,

The results of the MLP showed that age (0.169), grip strength (0.169), history of falls (0.164), Central Sensitization Inventory-9 (CSI-9) (0.131), and Athens insomnia scale (AIS) (0.126) were important predictors of LAPL (Table 3). The accuracy of the MLP model in predicting LPAL is shown in Table 4.
Table 3  
Predictors of Low Physical Activity Level by Multilayer Perceptron analysis

<table>
<thead>
<tr>
<th>Factor</th>
<th>Importance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>0.169</td>
</tr>
<tr>
<td>Grip strength</td>
<td>0.169</td>
</tr>
<tr>
<td>History of falls</td>
<td>0.164</td>
</tr>
<tr>
<td>CSI-9</td>
<td>0.131</td>
</tr>
<tr>
<td>AIS</td>
<td>0.126</td>
</tr>
<tr>
<td>BMI</td>
<td>0.080</td>
</tr>
<tr>
<td>Walking Speed</td>
<td>0.073</td>
</tr>
<tr>
<td>TSK-11</td>
<td>0.068</td>
</tr>
<tr>
<td>Sex</td>
<td>0.020</td>
</tr>
</tbody>
</table>


Table 4  
Accuracy of Multilayer Perceptron's Prediction Model

<table>
<thead>
<tr>
<th>Accuracy</th>
<th>AUC</th>
<th>Sensibility</th>
<th>Specificity</th>
<th>F-1</th>
</tr>
</thead>
<tbody>
<tr>
<td>MLP</td>
<td>81.0%</td>
<td>0.82</td>
<td>0.80</td>
<td>0.76</td>
</tr>
</tbody>
</table>

MLP: Multilayer Perceptron

Discussion

This study attempted to construct a model to predict low physical activity levels with data based on a cross-sectional survey of community-dwelling older adults with CP. Two models, LR and MLP, both found that history of falls predicted low levels of physical activity. Falls among older adults may lead to voluntary activity limitation, social isolation, depression, and adverse effects on quality of life [15]. Studies with a population of individuals with CP have shown that CP in older adults with problems related to physical activity, falls, and kinesiophobia has a significant impact on social participation, level of functioning, and quality of life [16]. The results of the present study support those of previous research. Older adults with CP and low levels of physical activity are either activity-limited due to their history of falls, or they have their own activity-limiting strategies. For older adults with CP and low physical activity levels, special attention should be given to fall prevention to promote physical activity. Exercises to improve balance, adjustments to medication, and facilitation of improvement of safety in the home are all important in fall prevention [17]. Some of the most important factors in fall prevention are described below.
MLP found that low level of physical activity in elderly people with CP was extracted from the CSI-9, a pain-related index, in addition to BMI and grip strength. Central sensitization (CS) in relation to CP is associated with hyperalgesia and with greater fatigue [18, 19]. Although it is already known that individuals with CP are negatively affected by CS, this study found that community-dwelling older adults with CP with low levels of physical activity were more affected by CS than individuals with CP who maintained moderate or high levels of physical activity. While it is important for individuals with CP to increase their level of physical activity, special attention should be given to individuals with low activity levels of CP. In addition, simpler tools to assess physical activity levels might be useful in rapid identification of individuals with low activity levels associated with CP.

MLP appeared to have superior predictive model accuracy. The advantage of ANN is that they mimic the mechanisms of cerebral neurons, can identify complex, nonlinear relationships between variables, and do not require a specific distribution of data. MLP based on ANN appear to be of clinical value for discriminating inactive community-dwelling elderly people with CP and provide useful information for consideration of appropriate interventions. Many previous studies have used LR when identifying predictors, but in future studies, it may be possible to construct more accurate models by using ANN and machine learning in addition to LR.

A limitation of this study is the small population. It was difficult to collect a sufficient sample of community-dwelling elderly individuals with CP, and this limited the independent variables for constructing predictors of community-dwelling older adults with CP and low activity. ANN are often used for big data analysis, so further analysis should be continued with more subjects. Studies using ANN for small samples have been published, so we should continue to monitor studies using ANN [20, 21]. In conclusion, this study was able to extract factors that predict low levels of physical activity based on reliable physical activity assessment results in community-dwelling older adults with CP. History of falls is an especially important factor in the low physical activity levels of individuals with CP.

Subjects and Methods Setting

This study was a cross-sectional analysis of data related to health checks conducted in cooperation between Osaka Kawasaki Rehabilitation University and Kaizuka City. Health checks were conducted at three community centers in Kaizuka City, Osaka, Japan, between 2021 and 2022. We report this study following the STROBE guidelines [22].

Participants

The inclusion criteria for this study were as follows: (1) ≥ 65 years of age; (2) living independently at home; (3) no cardiac pacemaker; and (4) presence of chronic pain. To confirm the presence of chronic pain, participants completed a self-report questionnaire on the definition by the International Association for The Study of Pain: "Chronic pain is pain that persists or recurs for longer than 3 months". To confirm the presence of chronic pain, participants were asked to answer "yes" and "no" questions on a self-reported questionnaire about the above definition (https://www.iasp-pain.org/advocacy/definitions-of-
chronic-pain-syndromes/). Those who answered "yes" were enrolled in the study. Individuals who could not answer the health check questions due to visual, hearing, or cognitive impairments were excluded from the study.

Ethical consideration

All participants provided written, informed consent to being part of the research study. This study was approved by the Osaka Kawasaki Rehabilitation University Ethics Committee (reference number OKRU30-A016) and was conducted in accordance with the Declaration of Helsinki.

Demographic data

Subjects were asked to fill out a self-administered questionnaire with their age, gender, height, and weight. Body Mass Index (BMI) was calculated by dividing their body weight (kg) by their height squared (m$^2$).

Daily Activity Assessment

IPAQ-SF was used to assess the degree of physical activity of the study participants [23]. It asks about three specific types of activity in four domains (leisure, work, household activities, and transportation) that took place in the previous seven days. The items are structured to provide separate scores for walking, moderately strenuous activity, and very strenuous activity. Respondents were categorized into one of three groups according to their physical activity level.

High Physical Activity Level (HPAL) was defined as any of the following:

a. Vigorous-intensity activity on at least three days achieving a minimum total physical activity of at least 1500 MET-minutes/week.

b. Seven or more days of any combination of walking, moderate-intensity or vigorous-intensity activity achieving a minimum total physical activity of at least 1500 MET-minutes/week.

c. Seven or more days of any combination of walking, moderate-intensity or vigorous-intensity activities achieving a minimum total physical activity of at least 3000 MET-minutes/week.

Moderate Physical Activity Level (MPAL) was defined as any of the following:

a. Three or more days of vigorous-intensity activity of at least 20 minutes per day.

b. Five or more days of moderate-intensity activity.

c. Five or more days of any combination of walking, moderate-intensity or vigorous-intensity activities achieving a minimum total physical activity of at least 600 MET-minutes per day.

d. Five or more days of moderate-intensity activity and/or walking of at least 30 minutes per day or minimum total physical activity of at least 600 MET-minutes/week.

Individuals who did not meet the criteria for Categories 2 or 3 were considered to have a 'low' physical activity level.
In this study, the HPAL and MPAL groups were combined into the HMPAL group and compared with the LPAL group to identify factors associated with individuals with low physical activity. The reason for this is that it has been shown that moderate or higher levels of physical activity in elderly people reduces the risk of developing chronic low back pain [24]. IPAQ-SF is a comprehensive, randomized, controlled study of the risk of developing chronic low back pain. In addition, ADCC was calculated based on the procedures defined in the IPAQ-SF.

Chronic pain related measure

CSI-9 was used to examine CS in individuals with chronic pain. CS is a physiological phenomenon in which dysregulation of the central nervous system leads to neuronal dysregulation and hyperexcitability, causing hypersensitivity to both noxious and non-noxious stimuli [25]. CSI-9 is a syndromic and self-reported questionnaire consisting of nine items that assess health-related symptoms common to individuals with the CS syndrome associated with CP [26]. CSI-9 is a shortened version of the 25-item CSI and higher scores indicate more severe CS. Subjects' kinesiophobia was assessed using the Japanese version of the 11-item Tampa Scale for Kinesiophobia (TSK-11). Kinesiophobia is defined as an excessive, irrational, and debilitating fear of carry out a physical movement due to a feeling of vulnerability to a painful injury or reinjury [27]. In TSK-11, higher scores indicate greater fear of movement or reinjury [28].

Physical function assessment

Grip strength was evaluated as an indicator of the degree of whole-body muscle strength. Grip strength was measured using a hand dynamometer (Grip-D; Takei, Niigata, Japan). Participants were instructed to walk 6.4 m (divided into 2-m zones at each end and a 2.4-m zone in the middle) at a speed they found comfortable. The time needed (s) to pass the 2.4-m middle zone was measured to calculate the gait speed (m/s). Participants could use a cane or walker if they were unable to walk without help. We used the average of five gait trials. In addition, a self-administered questionnaire was used to obtain information on history of falls. The subjects responded to whether they had fallen in the past year. Before answering this question, subjects were asked to pay attention to the following explanatory text regarding Gibson's definition [29]:

"Unintentionally coming to the ground or some lower level and other than as a consequence of sustaining a violent blow."

Clinical history

Insomnia was assessed using the AIS [30].

**Statistical analysis**
Subjects were classified into HMPAL and LPAL groups by IPAQ-SF. Missing data were excluded. Unpaired t test, Mann Whitney U test, and $X^2$ test were used to evaluate significant differences between the HMPAL and LPAL groups. LR was used to identify the factors most strongly related to the physical activity level of individuals with CP. Two regression models were created. The sample size required for LR was calculated using power analysis. The minimum sample size required for LR was 87, using a power of 80% and a significance level of 0.05.

Factors most strongly related to the physical activity level of individuals with CP were also extracted using MLP, one of the ANNs, and factors with high importance for the independent variables. Due to the small sample size, learning was set at 80%, physical activity level was used as the dependent variable, and all items measured in this study were used as independent variables. The network was set with the minimum and maximum number of units in the hidden layer set to 1 and 50, respectively, and the number of units in the output layer set to 1. The activation function consisted of hyperbolic tangent for both the output layer and the hidden layer. Predictive models with MLP were evaluated by Accuracy, AUC, Sensibility, Specificity, and F-1 scores. The statistical software used was IBM SPSS Statistics 27 (IBM Corp., Armonk, NY, US) with a significance level of less than 5%.

**Declarations**

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**Author contributions**

M.H. and R.I. were responsible for the conception of the study. All authors were involved in investigation. All authors reviewed and edited the manuscript and approved the submitted final version of the manuscript.

**Data availability**

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

**Competing interests**

The author(s) declare no competing interests.

**References**


**Figures**

![Flowchart illustrating the selection of study participants.](image)

**Figure 1**

Flowchart illustrating the selection of study participants.