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Prediction of health-related quality of life through health literacy, perceived social support, spiritual well-being, and resilience in patients undergoing hemodialysis: An artificial neural network study

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Abstract

Background and aims: An important factor for determining the efficacy of treatment for patients under hemodialysis is the health-related quality of life (HRQOL). This study aimed to examine the predictor of HRQOL among hemodialysis (HD) patients based on spiritual well-being (SWB), perceived social support (PSS), health literacy (HL), and resilience.

Methods: The present correlational study was performed on 260 patients randomly selected from the teaching hospitals of Ahvaz Jundishapur University of Medical Sciences. Data collection tools were a 36-item HRQQL questionnaire, Paloutzian & Ellison SWB scale, Zimet PSS scale, the Connor and Davidson resilience scale, and Montazeri and colleagues' HL for Iranian adults. Python software was used to conduct data analysis. Descriptive statistics, feedforward, and backpropagation algorithm in an artificial neural network (ANN) was used to determine the effect of studied variables on HRQOL.

Results: The mean age of patients was 51.73 ± 15.32 years. Most of the patients were married (76.9%), had low-income level (55%), and had at least one comorbidity (59.2%). The mean duration of hemodialysis machine use was 5.06 ± 3.43 years. Studied variables had grater impact on Physical QOL than the mental QOL. It was revealed that two dimensions of HL included evaluation skills (accuracy 0.92), accessibility skills (accuracy 0.92), and PSS (accuracy 0.88) were stronger predictors of physical QOL than other variables and SWB in the existence dimension (accuracy 0.80), understanding skills of HL (accuracy 0.76) and evaluation skills of HL (accuracy 0.75) were stronger predictors of mental QOL that other variables.

Conclusion: To improve the HRQOL of HD patients, we should increase HL, support social relationships, and improve meaning in life by giving importance to the SWB of these patients in providing care services to them.

Keywords: HD, PSS, Spiritual well-being, Quality of life, Health literacy, Resilience

Introduction

One of the biggest public health issues in the world is the rising incidence and prevalence of chronic kidney disease (CKD) (1). End-stage renal disease (ESRD) patients now have more treatment choices than ever before. Renal replacement therapy, hemodialysis (HD), continuous ambulatory peritoneal dialysis, and renal transplantation (RT) are the treatments of choice for this disease (2,3). By 2030, it is predicted that 5.5 million individuals would be dependent on dialysis and kidney transplants worldwide, much higher than the current number of 2.6 million(4). Advances in dialysis treatment have contributed to improved survival of patients with ESRD and their primary caregivers (partners) regularly say that quality of life (QOL) is a major issue when getting ready to start dialysis (5).

According to the statistics of 2016, the number of people with the ESRD across the world was 3 730 000, and 5%-6% is added to this number every year. The average prevalence of the ESRD in Iran is higher than the global average. At the end of 2016, 2 648 000 people worldwide and about 29 200 people in Iran underwent HD treatment(6). In Iran, the growth rate of the disease is about 12% per year, which is higher than the global average(7). Dialysis can extend life, but it cannot fully restore kidney function. Patients consequently deal with a wide range of psychological problems and concerns (8). Patients undergoing HD face a significant psychosocial burden, which is largely due to the disease's limitations, which include fluid and dietary restrictions. Physical and cognitive impairment, failure to adhere to the therapeutic regimen, reliance on treatment and health professionals, and dread of death are all factors that contribute to this burden (9). These patients must balance dialysis needs, comorbid conditions management,

dietary and fluid restrictions, and medications with personal, family, occupational, and social obligations. This self-management takes place in the context of common physical complaints including insomnia, exhaustion, and discomfort (10) that can have a detrimental impact on a person's capacity to function as well as on the physical and emotional aspects of QOL (11).

HD patients experience special conditions of illness and treatment and are exposed to various physical, mental, psychological, and social damage that will reduce their sense of subjective well-being (6). It is clear that knowing the factors affecting QOL and survival by modifying death risk factors will have a considerable impact on these patients (12). There is an increasing awareness in the literature that HD patients experience substantial impaired QOL (13). QOL is a key criterion for determining the success of health care, as well as one's overall health and well-being (14). It is made up of several concepts such as physical health, mental health, social health, and general health, all of which have an impact on the patients' QOL (15). It is a multidimensional concept that includes ability, function, health, well-being, and psychological condition, as well as values, goals, standards, and individual interests, as defined by the World Health Organization (16,17). Various studies showed that the QOL of HD patients is generally poor and significantly lower than that of the general population (18,19), and has not improved significantly in the last two decades (20). Previous studies have demonstrated that the modality of treatment in ESRD influences QOL of these patients (21).

Though significant progress has been achieved in understanding HD treatment, the importance of social support for HD patients is slowly recognized (12). In terms of psychology, social support can help people overcome depression and improve their QOL. As a result, social support can help patients cope with their condition. The ability of an individual to successfully endure and adapt to stress, obstacles, or environmental changes is referred to as resilience (22). Increased resilience plays a vital role in eliminating the stress encountered in illnesses; it also reduces physical disability and ameliorates stress-related damages (23). Patients with ESRD can improve their resilience by engaging in health-promoting behaviors, which can help them deal with stress and depression, allowing them to live a happier life. Therefore, resilience may be required for patients with HD to cope with the stress induced by the illness (24). Health literacy (HL), or the ability to read, understand, and act upon health information (25), is defined as the ability of individuals to access, analyze, and comprehend fundamental health information and services required to make informed health decisions (26). Limited HL is linked to poor medication adherence, elevated rates of hospital admissions, morbidity, and skipped dialysis treatments in patients with end-stage kidney disease (27,28).

Some studies on chronic diseases showed that the patient's self-confidence and religious faith are compromised (29). Accordingly, the mechanisms of adaptation and communication of the individual are disrupted due to uncertainty about the future and consequently a spiritual crisis appears in the individual. Spiritual disturbances cause grief in the patient and destroy the positive motivations for treatment (30). A sense of life purpose that justifies committing to something in life, as well as subjective well-being in terms of one's beliefs, are two ways that one can access one's spiritual well-being (SWB). Along with the physical, psychological, and social aspects of health, it is one of the four dimensions of human health (31). The literature review a need for more information about the role that spirituality plays in QOL. Therefore, there is a particular interest in examining the components of SWB in relation to the QOL (32).

It should be highlighted that, to date, no Iranian studies have been published that used artificial neural network (ANN) for health-related quality of life (HRQOL) assessment concerning SWB, HL, perceived social support (PSS), and resilience of HD patients. As a result, knowing how these factors affect HD patients' QOL can assist health care professionals to deliver them better care. In this regard, the current study aimed to assess the role of HL, PSS, SWB, and resilience on HRQOL of HD patients in southwest Iran.

Methods
Study design
This is a correlational study that used an ANN to evaluate the relationships of the physical and mental components of HRQOL (PQOL and MQOL) with PSS, resilience, two components of SWB, religion well-being (RWB) and existence well-being (EWB) and components of HL including reading, accessibility, understanding, evaluation, deciding and action.

Study population and sampling
The study population included patients referred to Ahvaz educational hospitals in 2021. Based on the number of studied variables and ANN as well as the sampling framework, 260 people were determined as the sample size. For this purpose, we considered 5% alpha, 80 standard deviations, and 30% error. The sample size calculation formula was below:

$$n = \left(\frac{z^2 1 - \frac{\alpha}{2} {}_{y^2} s^2}{d^2} \right)$$

First, a sampling framework was developed using 411 patients referred to three educational hospitals, including 245 patients who were referred to the Imam Khomeini Hospital, 80 to the Razi hospital, and 86 to the Golestan hospital based on their patients checklist. Based on the above framework, 205, 34, and 33 patients were randomly selected from these hospitals, respectively, using a table of random numbers. Nevertheless, 12 patients declined to take part in the study, and in the end, 260 patients

completed the questionnaire. The inclusion criteria were HD history for at least 6 months, age between 18 to70 years, being literate, and having communication skills. Exclusion criteria included lack of literacy and suffering from severe mental illness.

Instruments

Data collection instruments in this study included five questionnaires:

1. *SF-36 Health Survey:* The HRQOL was measured using the SF-36 questionnaire, a generic indicator of health. This questionnaire includes eight subscales relevant to the general health of the individual: Physical function (PF-10 items), role physical (RP-4 items), bodily pain (BP-2 items), general health (GH-5 items), social functioning (SF-2 items), role emotional (RE-3 items), vitality (VT-4 items), and mental health (MH-5 items). In addition, a single item that provides an indication of perceived change in general health status over a one-year period (health transition) has also been included in the SF-36. This scale is scored from 0 to 100, with 0 indicating the least favorable possible health status, 100 indicating the best, and those in between, the percentage of the total possible score achieved. In addition, two components scores consisting of physical component (PQOL = PF + RP + BP + GH) and mental component (MQOL = VT + SF + RE + MH) (33). The validity and reliability of the Persian version of this scale have been validated in several studies conducted in Iran and abroad. Validity and reliability in different dimensions have been obtained from 0.77 to 0.929 (34).

2. *Multidimensional Scale of Perceived Social Support (MSPSS):* This questionnaire designed by Zimet et al consist**s** of 12 items. This scale measures PSS from three sources: family (items 3, 4, 8, 11), friends (items 6,7,9,12), and significant others in one's life (questions 1, 2,5, 10). This instrument provides response options ranging from 0 to 6 (very strongly disagree to very strongly agree). The range of possible scores is 4 to 20 (35). It should be noted that the Cronbach's alpha coefficient of the PSS subscales, which has been widely used in Iran, has been reported to range from 0.76 to 0.89 (36).

3. *Health Literacy for Iranian Adults (HELIA):* This questionnaire was developed by Montazeri et al with 33 items that assess five dimensions consisting of reading (Re), access to information (Ac), understanding (Un), appraisal (Ap), decision making/behavioral intention. These concepts comprised the ability to read health materials (reading-4 items) to obtain health information (access-6 items); understand health information (understanding-7 items); ability to assess and evaluate the health information (appraisal-4 items); and to use the information to make a decision (apply or use health-

related information-12 items). A 5-point Likert scale is used to grade each question. Poor, moderate, and excellent HL are indicated by scores of 31-62, 63-124, and 125-155, respectively. In one study Cronbach's alpha coefficient of this questionnaire was 0.72 to 0.87 in five dimensions (37). This instrument was chosen because, in comparison to other HL tools, it covers all areas of HL, measures each dimension separately, and is simple to use and fast to complete. This instrument's satisfactory validity is confirmed by the fact that it has been utilized in several studies (38).

4. *Spiritual well being (SWB) Scale:* This questionnaire consists of 20 items and two subscales. The odd items are part of the religious well-being (RWB-10 items) subscale, which assesses an individual's satisfaction with their relationship with God. The even items are related to the existential well-being (EWB-10 items) subscale, which assesses purposefulness and life satisfaction. It is graded on a 6-point Likert scale, with 1 being strongly agreeing and 6 strongly disagreeing. Finally, people's spiritual health scores are divided into three categories: low (20-40), moderate (41-99), and high (100-120). The scale validity was determined using factor analysis and association with acceptable happiness, religion, and mental disorder scores(39). In an Iranian study, internal consistency and reliability in test-retest of this questionnaire were reported 0.85 and 0.90 respectively (40).

5. *Connor-Davidson Resilience Scale (CD-RISC):* The CD-RISC questionnaire has 25 items, each with a response in the range of 5 points as follows: Not applicable (0), rarely applied (1), occasionally applied (2), frequently applied (3), almost always true (4). Scales are scored based on how participants feel over the past month. The total score ranges from 0 to 100, with higher scores indicating greater resilience(41). In a domestic study, Cronbach's alpha coefficient and validity of this questionnaire reported 0.89 and 0.93, respectively (42).

Data analysis

First, the data were shuffled and normalized, then based on ANN**,** we considered 9 variables including social support, resilience spiritual health in the religious dimension, spiritual health in existence, accessibility reading skills, understanding, and evaluation, which were considered as the input layer, two hidden layers and two domains (PQOL and MQOL) as the output layer. Mean square of errors (MSE) and accuracy and false positive and true negative for each layer were calculated. The dataset was randomly divided into two sets: one set of 208 cases (80% of the overall dataset) for training the model and another set of 52 cases for testing the model. The model was built using the training set. Nine psychological characteristics of patients were the independent variables, and the outcome (HRQOL) was the dependent variable.

To conduct data analysis, Python software version 3.0 was used and the following activation function, feedforward, and backward algorithm were conducted:

Activation function: $y = 1/\left(1 + np.\exp(-1 * x)\right)$

Feedforward algorithm:

$Input = w1 -- \rightarrow x1, y1 = sigmoid(x1), y1 * w2 - \rightarrow x2$

$y2 = sigmoid(x2), y2 * w3 - \rightarrow x3, y3 - \rightarrow sigmoid(x3), y3 : Output$

Backpropagation:

$y = sigmoid(x) - \rightarrow d\_y = 1 * (1 - y)$

Results

The mean age of patients was 51.73 ± 15.32 and most of them were male and married (53.1%).

Most of the participants had primary education (36.2%). The occupation of most of the women was housewife (36.2%) and most men were retired (19.2%). Fifty five percent of patients had poor income. Most of the patients under HD (59.2%) had comorbidities (Table 1).

Values of ANN included MSE accuracy, false positive, and true negative considered for predicting PQOL and MQOL. These nine input variables had stronger relationship with PQOL than MQOL. Accessibility (MSE = 0.07, Accuracy = 0.92), evaluation skills of HL, social support, understanding skills, reading skills, deciding and action skills, SWB in the religious dimension, SWB in the existence dimension, and resilience had stronger relationship with PQOL, respectively. Spiritual health in the existence dimension, understanding skills, evaluation skills, SWB in the religious dimension, reading skills, social support, accessibility, deciding and action skills, and resilience was more correlated with MQOL respectively (Table 2).

For importance of each of variables in predicting of HRQOL, machine learning was used. For this purpose, 80% of samples was trained and 20% was tested in the algorithm of "learning" of ANN. Increased accuracy and decreased MSE values over the first 50 training rounds (ie, epochs) evidenced the most effective variable in predicting patients' HRQOL. Six variables with the greatest impact on the quality of PQOL as well as the MQOL is illustrated below (Figures 1 to 6).

Discussion

To the best of our knowledge, for the first time in Iran, this study predicted HRQOL in patients undergoing HD based on resilience via HL, PSS, SWB, and ANN. The results of this study showed that the PQOL of these patients was more influenced by the input variables investigated in this study. It was found that PQOL in HD patients was strongly affected by HL and PSS, and MQOL was strongly affected by SWB and HL.

The first finding of the current study showed that the most effective variable as the most predictor of HRQOL in HD patients is HL with three dimensions including accessibility, understanding, and evaluation. People

Table 1. Sociodemographic characteristics of HD patients (n = 260)

Variables	
Age (y), Mean ± SD (Min-Max)	51.73 ± 15.32 (17.00-93.00)
Gender, No. (%)	
Men	138(53.1)
Women	122(46.9)
Marriage status, No. (%)	
Single	46(17.7)
Married	200(76.9)
Divorced	4(1.5)
Widowed	10(3.8)
Children, Mean ± SD (Min-Max)	3.13 ± 2.37 (0.00-11.00)
Education, No. (%)	
Illiteracy	43 (16.5)
Primary education	94 (36.2)
Diploma	55 (21.2)
Associate Degree	36 (13.8)
Bachelor	28 (10.8)
Master of Sciences	4 (1.5)
Job, No. (%)	
Employee	26 (10)
Manual worker	6 (2.3)
Self-employed	41 (15.8)
Housewife	94 (36.2)
Retired	50 (19.2)
Pensioner	14 (5.4)
Student	2 (0.8)
Jobless	27 (10.4)
Income, No. (%)	
Weak	143 (55)
Moderate	101 (38.8)
Good	14 (5.4)
Excellent	2 (0.8)
Co-morbid disease, No. (%)	
Yes	154 (59.2)
No	106 (40.8)
Duration (y), Mean ± SD (Min-Max)	5.06 ± 3.43 (1-18)

with low HL may be at increased risk of experiencing psychological distress and difficulty in self-management. This finding is consistent with the results of a study by Dodson et al in Australia and Ebrahimi et al in Iran (13,43). Fraser et al in a systematic review realized that limited HL may represent an important determinant of poor outcomes in CKD, though a better understanding of causal mechanisms and the effectiveness of interventions to address HL is required (44). HL is considered a necessary factor to manage physical and mental health status (28). This condition is associated with several comorbidities such as coronary artery disease, hypertension, and diabetes mellitus, which can increase the need for information about their condition and self-management (45). HD

Table 2. Prediction of PQOL and MQOL based on 9 input variables of study (n = 260)

Variables	QOL							
	PQOL	MQOL	PQOL	MQOL	PQOL	MQOL	PQOL	MQOL
ANN values	MSE		Accuracy		False positive		True negative	
Social Support	0.1	0.22	0.88	0.67	6	17	46	35
Resilience	0.17	0.24	0.78	0.63	11	19	41	33
RWB	0.14	0.19	0.82	0.73	9	14	43	38
EWB	0.17	0.16	0.78	0.80	11	10	41	42
Accessibility skills	0.07	0.23	0.92	0.65	4	18	48	34
Reading skills	0.13	0.20	0.84	0.71	8	15	44	37
Understanding skills	0.11	0.17	0.86	0.76	7	12	45	40
Evaluating skills	0.07	0.18	0.92	0.75	4	13	48	39
Deciding and action skills	0.14	0.24	0.82	0.63	9	19	43	33
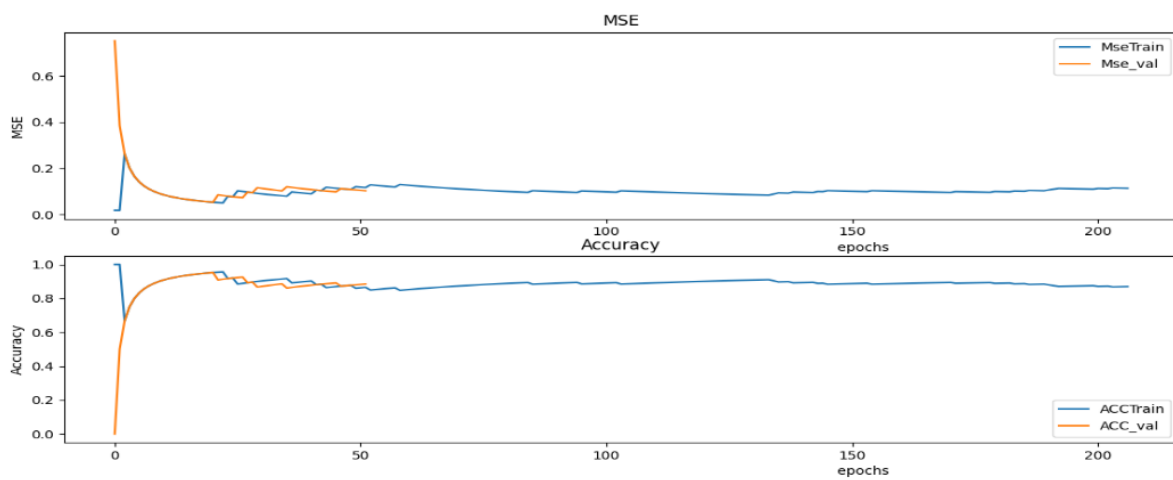
Figure 1. Machine learning algorithm shows increased accuracy and decreased MSE values over the first 50 training rounds (ie, epochs) for predicting PQOL based on PSS (Accuracy: 0.88, MSE: 0.1)
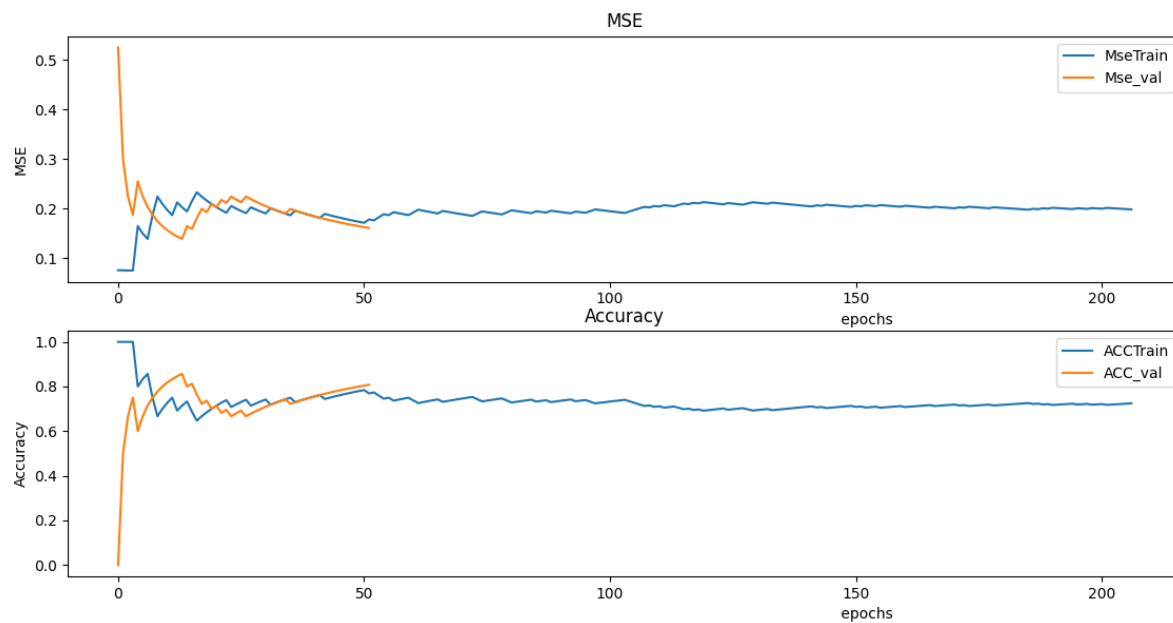
Figure 2. Machine learning algorithm shows increased accuracy and decreased MSE values over the first 50 training rounds (ie, epochs) for predicting MQOL through EWB (accuracy: 0.80, MSE: 0.17)
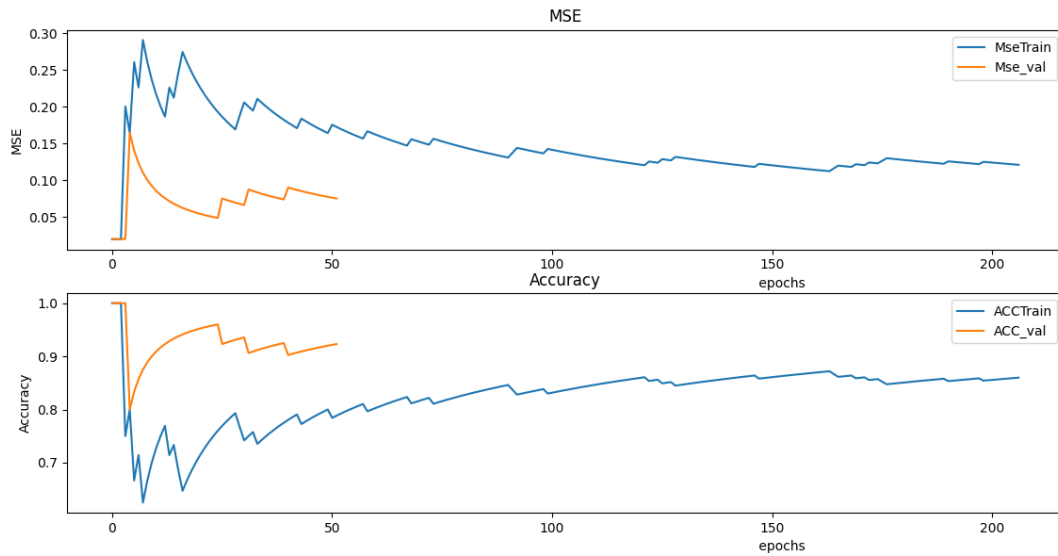
Figure 3. Machine learning algorithm shows increased accuracy and decreased MSE values over the first 50 training rounds (ie, epochs) for predicting PQOL through accessibility skills of HL (Accuracy: 0.92, MSE: 0.07)
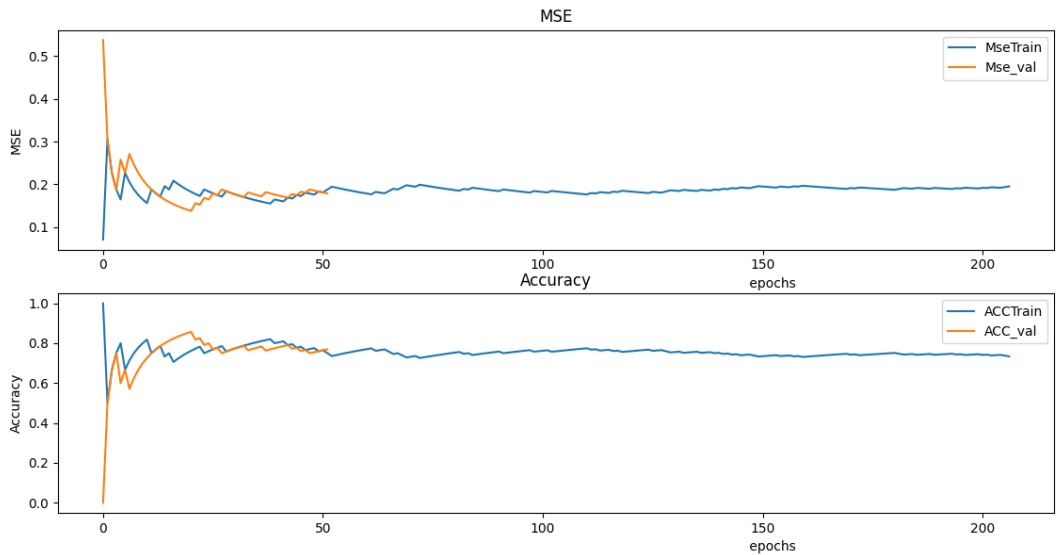
Figure 4. Machine learning algorithm shows increased accuracy and decreased MSE values over the first 50 training rounds (ie, epochs) for predicting MQOL and understanding skills of HL (Accuracy: 0.76, MSE: 0.17)
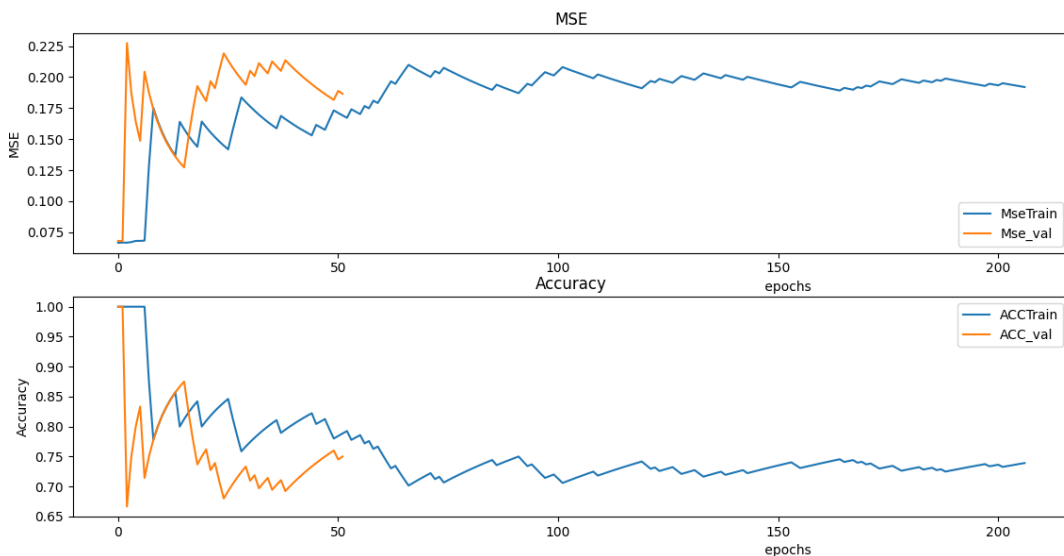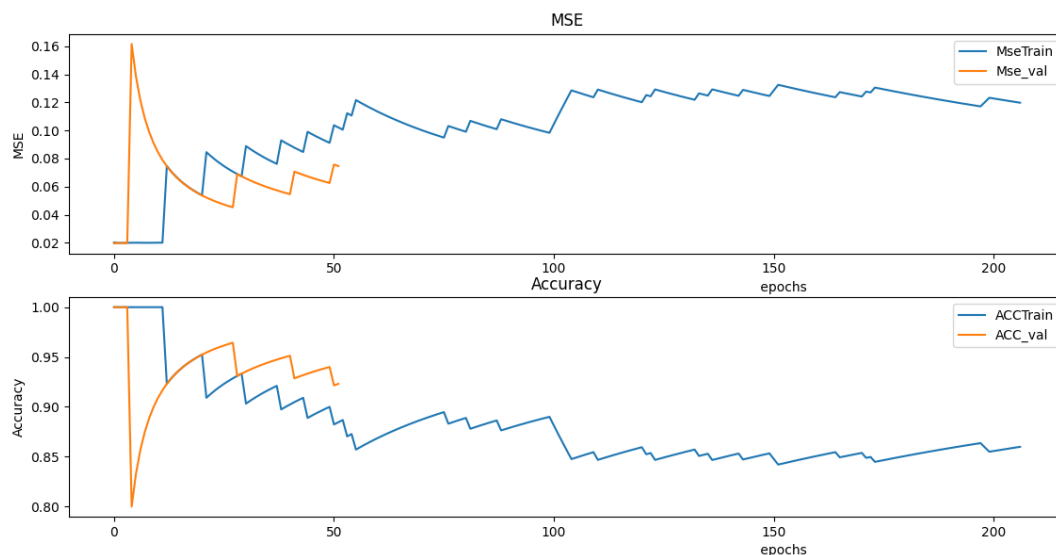

Figure 5. Machine learning algorithm shows increased accuracy and decreased MSE values over the first 50 training rounds (ie, epochs) for predicting MQOL and evaluation skills of HL (**a**ccuracy: 0.75, MSE: 0.18).

Figure 6. Machine learning algorithm shows increased accuracy and decreased MSE values over the first 50 training rounds (ie, epochs) for predicting PQOL through evaluation skills of HL (**a**ccuracy: 0.92, MSE: 0.07)

patients will typically have endured several complex symptoms for a prolonged period, chronic pain, insomnia, fatigue, breathlessness, and anorexia were recurrent symptoms (11). It is a crucial step for HD patients since they require dialysis two or three days a week to manage their condition and keep fluid and electrolyte balance. In addition, these patients must follow dietary guidelines on fluid intake, sodium, phosphorus, and potassium, and also take several medicines to manage and avoid problems related to CKD (46). Also, people with high HL are more prone to positive evaluation, instrumental support, and planning for challenging traumatic events. These strategies lead to self-management and continuous participation in the treatment process and interaction with health care professionals, which in turn leads to further promotion of HL, new assessments, and changing the meaning of the traumatic event in a positive way that can result in more growth (47). Appropriate HL allows patients to navigate complex treatment routes for renal disease, including end-stage kidney disease. It is characterized by the need for high doses of tablets and stricter fluid and dietary restrictions (48). An interactive HL framework is a relational concept that aligns patient skills and abilities with the needs and complexity of care packages (25).

Another finding of the study was the predictive role of PSS in PQOL. Social support has been consistently linked to improved health outcomes in numerous studies abroad, as well as in populations with various chronic illnesses with different geographic settings, socioeconomic statuses, and ethnic backgrounds (12,49,50). In this regard, Theodoritsi et al found that HD patients who had more support from others, family, and friends had remaining capability to maintain prior family or social roles (51). ESRD and its life-sustaining dialysis treatments impose a heavy burden on the patient's psychological and social life. Patients require time-consuming chronic treatment that limits

their ability to work, travel, and interact with family and friends. Adapting to life-sustaining techniques and long-term dependence on medical professionals increases their psychological distress. This stress is exacerbated by the demands and sufferings that other important people have to endure (12).

The other finding of this study was the prediction of MQOL based on SWB in the existence dimension. In this regard, Tanyi and Werner found that four major themes of spirituality (acceptance, understanding, fortification, and emotion modulation) could be involved in the psycho-emotional adjustment of renal disease patients (52). Religious coping may be one of the most important strategies for ESRD patients. Most patients have reported that religion helps them accept the illness, find peace of suffering, live with the illness, and cooperate more easily. Psychological symptoms can be alleviated by using a positive religious coping strategy (53). Spirituality may serve as an individual resource for coping with illness (54) and adaptation to the uncertainties associated with chronic illness, especially by promoting more adaptive coping styles and positive emotions when normal coping mechanisms, is ineffective (32).

It should be highlighted that the current study's questionnaires were self-report and therefore patient mental and psychological status, particularly during the COVID-19 epidemic, might limit the generalizability of the findings.

Conclusion

This study showed that improvement of HL, SWB, and PSS in patients undergoing HD had greater effect on their HRQOL, especially in PQOL. Because dialysis procedures are physical and the patient is constantly under these procedures, the physical aspect of QOL is much more important for these patients. HD patients need to improve their ability to read, understand, evaluate, and ultimately

respond to useful health-related content in order to improve their QOL. It has been demonstrated that HL, both as a cognitive and social skill, is necessary to enhance the patient's QOL because patients must be aware of and follow all dietary restrictions and medications that are provided as part of their treatment. Besides that, social support from families and other relatives is quite useful for HD patients in enhancing their QOL. In addition, spirituality, understanding of the meaning of life, and relationships with God are factors for maintaining and improving the QOL in these patients. These findings could assist in the identification of measures that could help HD patients improve their QOL, and it should encourage health care providers, spiritual care practitioners, and mental health providers to collaborate more frequently to coordinate a multidisciplinary approach to individualized patient care that includes aspects of HL, social support, and spirituality. It is needed to explore relationship of resilience and some other psychological factors with QOL of HD patients in the futures studies.

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Visualization: Fatemeh Hassani.
Writing – original draft: Fatemeh Hassani.
Writing – review & editing: Kourosh Zarea, Sally Wai-Chi Chan.

Conflict of Interests
The authors declare that they have no competing interests.

Ethical Approval
This study protocol was approved by the institutional ethics board of the Ahvaz Jundishapur University of Medical Sciences. Patients who agreed to participate in the study were made aware of the objectives of the study, and their data was assured to be kept private and confidential. As a result, written approval was received, and no expenses would be incurred.

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