Larix Publications

Advanced Journal of Robotics
https://ajrjournal.com/
Vol. 1, Issue 1, 2020

Research Article

Implementing a Physiotherapy Robot to Assist Disc Disease Patient

Corresponding author: Banan Emad Alshahwan *
Co-Authors: Ohoud Almousa, Rasha Alnuwaiser , Samah Alsoghyer , Zubaydh Kenkar and Nor Shahriza Abdul Karim

** Prince Sultan University, Saudi Arabia*
Email: benanemad7@gmail.com

Received on: 26-02-2020; Revised and Accepted on: 10-07-2020

ABSTRACT

This study discusses the implementation of Disc Disease Diagnosis (DDD) physiotherapy robot that attempts to assist the human physiotherapist. It aims to study the capability of a robot in performing DDD exercises, motivating patients and evaluating patient's acceptance. Human-Robot Interaction (HRI) was followed in the implementation. Experiments have been done with a real patient to obtain patient acceptance and motivation. Patient assessment toward physiotherapy robot is important by using: Technology Acceptance. The results from the observation and questionnaire was overall positive.

Keywords: *Robot; NAO; Physiotherapy; Physiotherapist Robot; Disc Disease Diagnosis; DDD.*

1. INTRODUCTION:

Over the next decades, the facts of the population are shocking where the patient percentage will increase while the percentage of the available people who take care of them will decrease. This will result in a social problem that researchers, entrepreneurs, and governments are already trying to solve [1].

Degenerative Disc Disease (DDD) associated with aging. With age increasing, the human's disc and spin may be degenerated and weaken. It may perhaps be observed that DDD can occur in people as young as 20. DDD is increased over time, and the pain arises when conducting more activities. There is no cure for DDD but it can be mitigated through exercises to reduce the pain and other symptoms [2].

DDD can involve any part of the spine, but it most commonly impacts the low back. Lower back pain is a severe medical issue influencing 84% of individuals at some phase of their life [3].

***Corresponding Author**:
Banan Emad Alshahwan, Prince Sultan University, Saudi Arabia. Email: benanemad7@gmail.com
DOI: https://doi.org/10.5281/zenodo.3938843

Lower back pain causes disability that affects the life quality of patients besides economic issues that increase the cost of healthcare, especially for the patient. Surgery can be a solution for DDD but usually in the best interest of most patients to manage their low back pain using non-surgical approaches. Thus exercise therapy is proposed as it has been proven to be an effective long-term method of rehabilitation and treatment of lower back pain for adults including patient people. Low back pain is a prevalent problem frequently reported in older people [4]. Low back exercises could include knee rolling, pelvic tilting, knees to chest, back extension exercises [5].

Besides the lack of physiotherapy specialists, the cost of physiotherapy treatment is a barrier to have regular physiotherapy sessions which is an essential factor for success in DDD treatment. Therefore, technology has been utilized in physical therapy for a long time. Moreover, robots could help in degenerative disc diseases treatment for patient people [6]. Treatment robots have been assigned to several responsibilities in healthcare. However, there is a limited research on physiotherapy treatment and in particular DDD treatment. To the best of our knowledge, this is the first study that implements suitable exercises for DDD in robots to be presented to patients in physiotherapy sessions in order to measure the acceptance and evaluate the motivation.

2. LITERATURE REVIEW

This literature covers most of the previous research that have been done in robot acceptance, robot in rehabilitation, robot in motivation and robot evaluation.

2.1. Robot acceptance

Robot acceptance has extensive literature within Robots. On this paper [7] the study was focusing on the acceptance of robot in healthcare sector for patient people based on age and gender, the robot “Charles” was able to communicate with patient patients and measure the blood pressure for them. The experiment was on middle-aged patients with 45 to 65 years and old patients who are over 65 years; the result shows that there is no significant difference in the number of patients who accept the robot, as the writer mentioned the reason behind the difference is older people are less practice of technology. On the other hand, there is a notable difference between males and females in robot acceptance. Actually, men were most accepted of the robot more than women. Another segment of acceptance can be children as a research has been conducted to study how children interact and form a friendship with the robot. This study was conducted on 184 children between the ages of 5 and 15 years. The result was positive for the children to get in touch with the robot and share their activities. Because of this, the robot is considered a suitable friend for children [8].

2.2. Robot as physiotherapists

In previous study [9], where 30 patients were divided into two groups of patients with hemiparesis robot group and control group. The condition of each elderly was recorded before starting treatment. Each group underwent half an hour of 20-day treatment. The robots group exercise also received 30 extra minutes over 20 days. At the end of the treatment, A clinical examination was conducted to determine the condition of each elderly and comparisons were made before and after treatment in both groups and statistically evaluated by t-test and Friedman’s test, the result was positive. This indicates that robots can replace a specialist’s physiotherapists. In another research [10], it was found that the robot is advantageous in the medical field, especially in medical rehabilitation. This was concluded by conducting studies and tests of three mechatronic systems after stroke, and it was found that intensive training comes with a positive result after a period of time and the elderly can move and control the limbs.

Furthermore, researchers [11] used robots as elderly care robots to improve quality of life for elderly people. They developed an extension to the NAO robot called RIA to interact with the elderly. RIA also includes multiple sensors to measure body and environment temperature, blood pressure heart rate, etc. to create a better environmental place for elderly for example alert the elderly or the person in charge if the temperature becomes abnormal.

2.3. Robot Evaluation

As a robot evaluation is considered to prove the project’s effectiveness. A study [12] of the robot performance was tested as a personal trainer for the elderly to perform physical exercises. Using the vision processing unit, the movements of the hand and face are monitored and reported to evaluate and analyze the progress of their performance. Besides, A usability testing has been conducted to assess the acceptance level of elderly and their interaction with the robot. Elderly s' responses were collected and therefore the result was some improvements to the functionality and ease of use of the robot . In another study [13], the robots were used for five weeks in a center to provide assistance to the elderly. Through this robot, the facial expressions of the elderly were determined, the psychological condition was determined, and stress was determined through urine tests. The result was very positive for the interaction of older people with the robot and psychological improvement and also improved as a result of urinary tests. The robot has achieved great success in caring for the elderly.

Since the used robot type for the project is Nao, researchers [14] presented an LTI model by using experimental data for the calculations and validation to control the robot position in some dimensions. They used several inputs and outputs to model the robot walking. Although any position of NAO robot can be achieved by dividing its path into some shorter sub-paths. Accordingly, the proposed a simple model that covers right movement is considered to control as well as make the calculations simple, applicable to manage in a real experience.

2.4. Robot in Education

Robot NAO is a device consisting of arms and legs that enable him to move flexibly, and there are sensors in his head and also a camera that allows him to monitor and sense the people around him. Therefore, Robot NAO achieved success in the field of education [15]. It was employed with teenagers between 11 and 16 years, where they taught him to shed some of the poems in the Danish language. Also the robot was able to distinguish some movements and gestures of students and interact with them in addition to adding fun and excitement to education.

2.5. Acceptance Model

Davis proposed a Technology Acceptance Model (TAM) to evaluate the acceptance of new technologies by using two fundamental factors Perceived Usefulness (PU) and Perceived Ease of Use (PEU) [16]. Many types of research have been conducted to rate the acceptance of technologies by using TAM. In [17], the acceptance test for seniors was performed for robot-assisted use using TAM and also in [18] and [19]. A test was also conducted to evaluate the acceptance of the elderly of the robot. The result was positive for the elderly to accept the robot and enjoy for interacting with it. In our approach will use

TAM model to be followed in evaluating the acceptance of the physiotherapy robot.

3. METHODOLOGY

Ten layers of research protocol methodology for HRI innovations was followed in this research [20]. Shamsuddin et al. proposed that it is critical to consider these ten layers into account prior initiating any robot intervention program. These protocols can be a guideline for researchers to help them plan for a robot project. Also, these layers could improve the project output regarding duration, intensity, and setting. The ten layers are discussed in details in the next sections

3.1. Establish aim of the human-robot interaction (HRI) program

This study aims to evaluate the motivation and acceptance level of people who suffer from a degenerative disc disease and their attendance commitment to further therapy sessions. An implementation was applied on NAO robot for a set of exercises that are suitable for DDD patients. Before the implementation stage, we have identified a set of exercises that suits the condition and decided what type of interaction scenarios will be designed and the duration of the exercise sessions. This was achieved by collecting data from previous studies, interviews with therapists, brochures from official hospital websites, and videos about disc exercises to procure the information necessary for establishing our novel study

3.2. Define the exercises and design the interaction scenarios

We utilized interview and observation methods to identify the exercises of degenerative disc patients and to gather requirements that we need to implement our project. Moreover, we got back to the previous researches that researchers have conducted on robots to serve patients. We performed different interviews with physiotherapists and experts in this field. In the interviews we were trying to cover various and significant hospitals in Riyadh- Saudi Arabia such as King Fahad Medical City (KFMC) and National Guard Health Affairs (NGHA). The physiotherapists have different levels of experience from fresh graduate to Supervisor of Physical Therapy Department. The primary objectives of the interviews are:

a. Find out the standard disc exercises.
b. Define the most types of the disc disease where most people are infected.
c. Highlight the most suitable exercises for the selected type of disc.
d. Find out if patients committed to therapy sessions.

In the interviews the below questions have been asked:

a. Information was collected about the interviewee name, hospital or physiotherapy center name and job title and role.
b. What are the most common exercises for disc?
c. What are the most common types of disc?
d. What are the most needed exercises for the elderly?
e. Are patients committed to therapy sessions?

After conducting the interviews, we observed disc exercises. Then we learned how to apply those exercises from various sources such as physical therapists, videos and brochures from hospital's official websites and medical colleges such as Oxford University Hospital [5].

Moreover, from previous researches, we tried to find out about relevant details that are related to patient acceptance of robot. Also, various evaluation tools that can be used to assess the robot and the provided exercises. More valuable information was obtained about the robot as physiotherapist, robot and motivation, robot social effect and the best methodology to perform robotic research.

After collecting the data from interviews, observation and previous robotic studies, we gathered all information on google drive and conducted several team meetings to discuss and analyze the data by looking into the commonly given exercises and prioritize them to see what is best for the patient and at the same time applicable by NAO robot. The primary tools used in data gathering are Microsoft office and google drive to be able to access and share information among all team members. We also used descriptive statistics analysis tool for analyzing data collected during the experiment.

The scenarios are written based on selected exercises that have been approved by physical therapists. According to the objective of this research, the robot delivers beneficial exercises for with disc disease and at the same time motivate them to get better results

Table 1. Lunch robot scenario

Scenario: Lunch Robot		
No.	Section	Content
1	Identifier	s-1
2	Name	Lunch robot
3	Author	All team

4	Version	V.1.0
5	Change history	-
6	Priority	High
7	Criticality	High
8	Responsible stakeholder	All team
9	Short description	The robot introduces himself, welcome patient and brief the patient about exercises.
10	Scenario type	Interaction scenario
11	Goal(s)	To introduce the exercises and motivate the patient
12	Actors	Robot, patient
13	Precondition	Boot Nao robot by pressing the chest button once to turn it on.
14	Post condition	-
15	Scenario steps	1. The robot welcomes the target patient with different greeting sentences (randomly selected like "Hello" and "Hi there") 2. The Robot introduces himself "my name is NAO, I will assist you in today's session" 3. The robot asks patient if he is ready "So, are you ready?" 4. The target patient answer the robot 5. According to the patient's answer: 5.1 If the answer is yes: the robot will start the first exercise scenario. 5.2 If the answer is no: 5.2.1 The robot will say "Hum, okay I'll wait for you" 5.2.2 The robot will wait for 1 minute unless the patient talks, then the robot will go again to step 3 in this scenario and will proceed to next steps.
16	Relationships to other scenarios	S-2 S-3 S-4 S-5
17	Supplementary information	This scenario is followed every time the robot is launched

Table 2. Single knee to chest exercise scenario

Scenario: Single Knees to Chest Exercise		
No.	Section	Content
1	Identifier	S-2
2	Name	Pelvic Tilt exercise
3	Author	All team
4	Version	V.1.0

5	Change history	-
6	Priority	High
7	Criticality	High
8	Responsible stakeholder	All team
9	Short description	The robot recognizes the patient's speech for yes and starts this exercise. All movements in the exercise are performed and pronounced at the same time. The exercise will be repeated twice, The first to show the movements of the exercise without imitating the robot. During the second iteration of the exercise, the patient should imitate the robot movements.
10	Scenario type	Interaction scenario
11	Goal(s)	To perform single knees to chest exercise
12	Actors	Robot, patient
13	Precondition	S-1
14	Post condition	-
15	Scenario steps	1. The robot says “Great, then let's start with the first exercise which called single knees to chest stretch. But first, you are going to watch me. I will do the exercise twice. The first time you just watch me, in the second time you will imitate me.” 2. The robot lies on the back with knees bent and says “To begin, lay on the floor” 3. The robot flattens the lower back onto the floor and bending the pelvis up slightly 4. The robot extends the right leg straight and pull the other knee to chest and says “First, extend your right leg straight and pull the other knee to your chest. Hold your knee using both hands”. Then the robot says “Hold for up to 10 seconds and Keep your breath smooth and even” 5. The robot release and extend both legs along the floor and switch to the other left leg and says “now release this leg and extend both legs along the floor and switch to the other left leg ” 6. The robot extends the left leg and says “extend your left leg straight and pull the other knee to your chest. Hold your knee using both hands” 7. The robot applies this in gently motion for 30 seconds to 1 minute. 8. The robot says ”Now it is your turn, please lay down to start the exercise”

		9. The robot asks the patient “Did you lay down?” 10. According to the patient’s answer: 10.1 If the answer is yes: the robot will start the exercise 10.2 If the answer is no: the robot will wait for little time and asks again “Did you lay down? 11. The robot will repeat the steps 4, 5, 6 and 7 12. The patient should mimic the movements of the robot 13. While the robot is performing the exercise, the robot says some phrases to motivate the person like "come on you can do it", "keep it up", "you are a hero" and finally says “One more and you're done ” 14. The robot finishes the exercise and thank the person with words of encouragement like "good job" and " I'm so proud of you" and finally says “Good work, Now have a break for a minute and then we will move to the second exercise ”
16	Relationships to other scenarios	S-1
17	Supplementary information	-

Table 3. Double knee chest exercise scenario

Scenario: Double Knee Chest Exercise		
No.	Section	Content
1	Identifier	S-3
2	Name	Straight Leg
3	Author	All team
4	Version	V.1.0
5	Change history	-
6	Priority	High
7	Criticality	High
8	Responsible stakeholder	All team
9	Short description	The robot recognizes the patient's speech for yes and starts this exercise. All movements in the exercise are performed and pronounced at the same time. The exercise will be repeated twice, The first to show the movements of the exercise without imitating the robot. During the second iteration of the exercise, the patient should imitate the robot movements.
10	Scenario type	Interaction scenario
11	Goal(s)	To perform double knee chest exercise
12	Actors	Robot, patient

13	Precondition	S-1
14	Post condition	-
15	Scenario steps	1. The robot says "We will start double knee chest exercise. I will do the exercise twice. The first time you just watch me, in the second time you will imitate me". 2. The robot lies on the back with knees bent and the feet on the floor and says "To begin, lay on the floor" 3. The robot pulls both knees off the floor toward his chest and says "To start, put your knees on your chest without using hands " 4. The robot says "Pull your knees for 1 minute" 5. During the 1 minute pose, the robot says "Don't forget to breathe and make sure to keep your knee on 90 degrees" 6. The robot says "Now it is your turn, please lay down to start the exercise" 7. The robot asks the patient"Did you lay down?" 8. According to the patient's answer: 8.1 If the answer is yes: the robot will start the exercise 8.2 If the answer is no: the robot will wait for little time and asks again "Did you lay down? 9. The robot will repeat the steps 2, 3, 4 and 5 10. The patient should mimic the movements of the robot 11. While the robot is performing the exercise, the robot says some phrases to motivate the person like "come on you can do it", "keep it up", "you are a hero" and finally says "One more and you're done " 12. The robot finishes the exercise and thank the person with words of encouragement like "good job", " I'm so proud of you" and "great job, you're done with this exercise". Finally says "Feeling good ? Now have a break for a minute and then we will start with the last exercise"
16	Relationships to other scenarios	S-1
17	Supplementary information	-

Table 4. Straight leg exercise scenario

Scenario: Straight Leg Exercise		
No.	Section	Content
1	Identifier	S-4
2	Name	Straight leg
3	Author	All team
4	Version	V.1.0
5	Change history	-
6	Priority	High

7	Criticality	High
8	Responsible stakeholder	All team
9	Short description	The robot recognizes the patient's speech for yes and starts this exercise. All movements in the exercise are performed and pronounced at the same time. During the exercise, the patient should imitate the robot movements.
10	Scenario type	Interaction scenario
11	Goal(s)	To perform straight leg exercise
12	Actors	Robot, patient
13	Precondition	S-1
14	Post condition	-
15	Scenario steps	1. The robot says "I am going to make you so proud, let's start the last exercise" and then says "Please follow me " 2. The robot says "We will start straight leg exercise. We will do it in both legs 3 times each" 3. The robot says "Please lay down to start the exercise" 4. The robot asks the patient "Did you lay down?" 5. According to the patient's answer: 5.1. If the answer is yes: the robot will start the exercise 5.2. If the answer is no: the robot will wait for little time and asks again "Did you lay down? 6. The robot will start the exercise by bending the left leg and keep the right leg straight and left it up 7. The robot says "Now bent your left leg and try to keep the right leg straight and left it up as much as you can" 8. The robot will keep the right leg straight and lower it to the floor 9. The robot will say "Now slowly lower your leg to the floor and repeat that again" 10. The robot will repeat step 6 and 8 again 11. The robot hold the right leg with hands and says "If you could not balance yourself you can hold your leg like this" 12. The robot will repeat step 6 and 8 again 13. The robot switch between legs: bent the right leg and keep the left leg straight and left it up 14. The robot will keep the left leg straight and lower it to the floor 15. The robot will say "switch and repeat for the left leg" 16. The robot will repeat step 13 and 14 again 17. The robot says "Good job You master it. Now repeat it up and down for the third and last time" 18. The robot will repeat step 13 and 14 again 19. The patient should mimic the movements of the robot 20. While the robot is performing the exercise, the robot says some phrases to motivate the person like "come on you can do it", "keep it up" and "you are a hero" 21. The robot finishes the exercise and thank the person with words of encouragement like "good job", " I'm so proud of you" and "great job, you're done with this exercise". Finally says "Feeling good ? Now have a break for a

		minute and then we will start with the last exercise”
16	Relationships to other scenarios	S-1
17	Supplementary information	-

Table 5. End session scenario

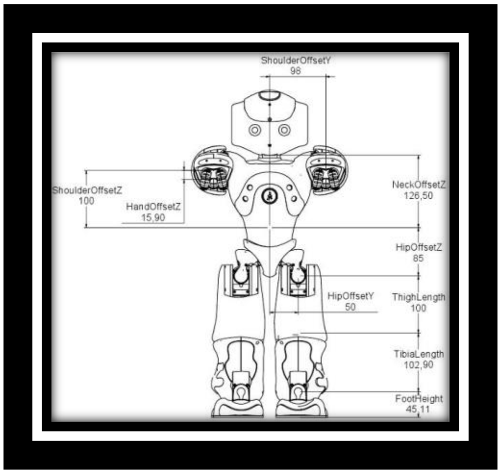
Scenario: End Session		
No.	Section	Content
1	Identifier	S-5
2	Name	End session
3	Author	All team
4	Version	V.1.0
5	Change history	-
6	Priority	High
7	Criticality	High
8	Responsible stakeholder	All team
9	Short description	The robot will finalize the session.
10	Scenario type	Interaction scenario
11	Goal(s)	To end the session
12	Actors	Robot
13	Precondition	S-1
14	Post condition	-
15	Scenario steps	1. The robot says “Well done, you have done a great job and I'm looking forward to your next session. Have a great day and see you soon” 2. The robot will wave and say “Bye” 3. The robot will turn off
16	Relationships to other scenarios	S-1
17	Supplementary information	-

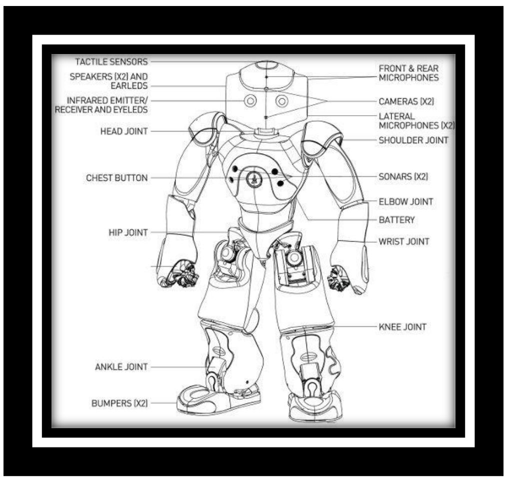
3.3 Program the robot for interaction

a. Hardware

NAO robot is an interactive companion robot used in our experiments to practice the exercises and motivate the patients. The robot is 58 cm height and weight about 9.5 lb. NAO has 25 degrees of freedom and equipped with two HD cameras, four microphones, two speakers. Figure.1 shows the physical details of NAO robot.

Fig. 1: NAO robot details





b. Software

NAO robot has an Integrated Development Environment (IDE) called Choregraphe. This tool enables us to create animations and any behavior that we can test on a simulated robot on the screen. Using Choregraphe software behaviors can be applied directly to the physical robot through a Wi-Fi connection. Choregraphe has also simple drag and drop interface for general functions such as repeating set movements and making sounds. Further, NAO robot can be programmed using many programming languages like Java, MATLAB, C++ and Python. Also, we downloaded ALPhotoCapture module from the store to be able to use the cameras then take pictures and save them on disk. For the language, English is the default language and we purchased a plugin for Arabic language.

Pre-implementation

In this research, the following modules were used and modified to implement the human-robot interaction:

● ALSpeechRecognition, this module gives the robot the ability to recognize the defined words when the participant response.

● ALTextToSpeech, this module allows the robot to speak and provide all the instructions during the session to the participant.

● ALFaceDetection, this is a vision module which enables the robot to detect the participant's face in order to start the session.

Implementation

Three exercises scenarios were identified after collecting information from different resources such as hospitals' brochures and interviews with physiotherapists. Also, two other scenarios were pointed out to cover initiating and finalizing the therapy session between the patient and the robot. Python used to implement the whole program. The program starts with Lunch Robot Scenario (initiating scenario). Then, the program will run three scenarios; Single Knees to Chest, Double Knee Chest and Straight Leg, respectively. Finally, the program finalized with End Session Scenario. There are time breaks between scenarios where the robot asks the patient to continue the session or not.

Each scenario was implemented in a set of boxes which are executed sequentially or simultaneously. Each box represents a behavior such as timing weight, making the robot talk or move in a specific way. The boxes(behaviors) communicate with each other through connectors to control the flow of the scenarios. Also, each box could contain inner boxes to implement complex behaviors. Figure.2 shows a snapshot of the project implementation.

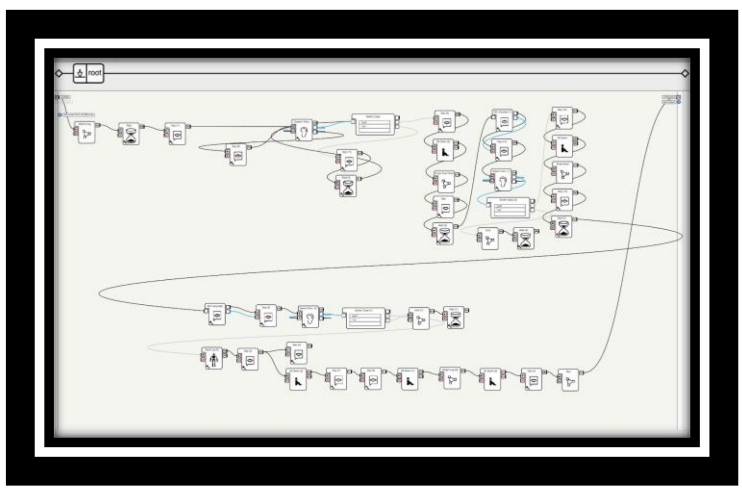


Fig. 2: Snapshot of program

C. Testing

For the robot software, we applied unit testing, integration testing and system testing. We used white and black box testing, we also tested the program in a simulator first then in the robot. We ensured all test cases are passed and presented the robot free of errors to physiotherapists and

patients. Moreover, during the testing phase, the focus was on three aspects namely timing, exercise sequence and interaction. This because the robot is going to perform autonomously. Full system testing supported us to get excellent results in our experiments.

3.4. Ethics approval

According to Shamsuddin et al. [20], researchers who involve human subjects in their research have an ethical responsibility. Ethics approval is a fundamental part of clinical practice etiquette, with which researchers are required to comply. Since our proposed program for patient individuals with a disc diagnosis involves human participants, it is necessary for us to obtain ethics consent from National Guard Health Affairs (NGHA). NGHA gave feedback about the implemented program and provided patients to participate in the experiment. Ensuring the comfort and wellness of the participants in the experiments and protecting their rights is of the utmost importance.

3.5 Subject selection based on inclusion criteria and diagnosis patient's condition and ability

The study criteria for accepting patients as participants are:

1. Have a confirmed diagnosis of DDD

2. Are not hearing or/and vision impaired

3. Should speak Arabic

4. Are not paralyzed and do not need to use a wheelchair

5. Have the ability to perform the exercises without the help of an assistant.

3.6. Patient consent and briefing to therapist

The next stage is to get written approvals from the selected patients or his/her family to participate in the program. It is a standard to ask the patient in the consent form to approve that he/she is a voluntary patient [20].. The written approvals also admit that the participant can leave the experiment at any time. In our study, the presence of physiotherapists is required to guarantee patient's safety. Also, a preparation session conducted with the physiotherapists before applying the actual experiments on the patient. This is to point out the need for their attendance as well to make sure that they should not hinder the aim of the study. The therapists are going to join the session without giving any assistance or instructions to the patient. Their presence is to support us with evaluating the patient interaction and performance in addition to the robot.

3.7. Elderly-robot interaction

The experiment was conducted at the National Guard Health Affairs (NGHA). One volunteer patient was obtained from the physiotherapy department. The patient selected for the study had a confirmed diagnosis of DDD, no hearing or vision deficits, fluency in spoken Arabic, and able to follow and perform exercises without any assistance. Before the interaction, we gave guidance to the participant about the whole session and some commands for responding to the robot. The patient performed two sessions, one each week. The experiment took place in one of the physiotherapy rooms, which was located in the physiotherapy department. An exercise mat was prepared for the participant, which was placed next to the robot as shown in Figure 3.

The robot was working autonomously and continuously executed the five interaction scenarios. The session duration was 30 minutes, including a break between each exercise. The robot began in a static, standing position. Once the robot detected the patient's face, the robot started the session by welcoming and introducing himself to the patient. Following that, the robot asked the participant patient if he was ready to start the session. The robot reacted based on the participant's response and continued executing all the scenarios as described in section 3.2, starting with a single-knee chest exercise. At the end of the exercise, the NAO robot gave the patient a break for a minute. Then the robot asks if the participant needs to continue the exercises, prompting the session to start the next exercise. The patient was able to perform both sessions successfully without any rejection.

Two team members observed the patient to evaluate the patient's motivation level during the session. Physiotherapists were also taking the role of the observer to assess the patient's acceptance level by filling out the questionnaire at the end of the session.

(a)

(b)

Fig 3. Show the patient while performing (a) double knee-chest and (b) straight-leg exercises with the robot

3.8. Data analysis

Questionnaires and observation methods were used during each session to collect information. The questionnaires were distributed to evaluate the patient's and physiotherapist's acceptance using TAM model. Tam model measures the following criteria:

a. Perceived usefulness (PU) which indicates user believes in robot usefulness
b. Perceived Ease of Use (PEOU) that shows the degree of user believes that robot is easy to use
c. Intention to use (ITU) that indicates the performance of specific behavior using technology.
d. Social Presence (SP) that indicates the system's ability to perform social behavior.
e. Perceived enjoyment (PENJ) that indicates the rate of enjoyment during the use of technology.

The observation method was used to evaluate the motivation during the session. The following questions are used:

1. Did the patient replay (Hello) to the robot.

2. Was the patient ready to start exercise?

3. Can the patient hear/ understand the Robot speech?

4. Did the patient follow robot exercise?

5. Was the patient ready to take the position of the exercise?

6. How was the patient reaction toward robot's encouragement phrases?

7. Was the patient motivated to do the second and third exercises?

8. Was the patient willing to continue with the robot?

9. How was the patient's reaction toward the session' closing?

10. How was the patient's reaction toward the closing statement by robot.

4. RESULT

The experiment was conducted at National Guard Hospital Affairs. The experiment sessions divided among two sessions, having a same volunteer patient that is suffered from Degenerative disc and already took his therapy at NGHA. The assessment is done for each session using the tools of: observation and the questionnaire. Both acceptance and motivation were evaluate using Technology Acceptance model (TAM) which was initiated by Davis in 1989 [16]. This model shows the following factors; the perceived usefulness (PU), perceived ease of use (PEOU), Intention to Use (ITU), Social Presence (SP) and perceived enjoyment and (PENJ). The result of the observation during the sessions was positive in terms of patient acceptance where the physical therapy exercises follow with the robot goes smoothly. The result of the questionnaire that handed to both: physiotherapist and patient was also positive and found that the physiotherapist robot enjoyable but they have not seen that the physical therapy robot alone can help the patient to improve his health faster than stand with real physiotherapist.

4.1. Results questionnaires

In the questionnaire, the questions were designed in the same way of previous researches [18, 19, 21]. It was designed based on technology acceptance model (TAM). The questionnaires were prepared to obtain statistical information throughout the experiment sessions. The questionnaires handed to the physiotherapists and the patient to get their response. The physiotherapist's response was recorded in the live observation during the patient session. The patient's response showed a high acceptance of the robot and approved the motivation of robot.

Physiotherapist Response:

The questionnaire handed over to the physiotherapist in the session. The physiotherapist was required to fill it and return it to the researchers. An open feedback question is an option listed already on the questioner. For both sessions, the physiotherapist collaborated to fill the questionnaire and provide his comments. The response was too similar between the two sessions. By scanning the response from the questionnaire, the physiotherapist still looking to have full interaction between the robot and the patient. Additionally physiotherapist still convinced that robot's exercises alone are unable to improve the patient's condition quickly unless applying the sessions under the physiotherapist control. At the first session, the physiotherapist commented "Very Interesting and great possibilities". While in the second session, the physiotherapist suggested developing the robot to perform exercises for a group therapy patients to increase the motivation among the group.

Table 6. Physiotherapist questionnaire

#	Code	Questions	Yes	No
1	PENJ	Do you notice the patient enjoying performing the physiotherapist exercise?	yes	
2	PENJ	Do you notice the patient is getting boring during physiotherapist exercise?		No
3	PEO U	Do you find it easy to get a robot for physiotherapist exercise to do what you want it to do?	Yes	
4	PEO U	Do you notice the patient's performance of the physiotherapist exercises with the robot correct and clear?	Yes	
5	PEO U	Do you find the robot is flexible while performing the physiotherapist exercises?	Yes	
6	ITU	Do you think you will use the NAO robot for physiotherapist in the hospital in near future?	Yes	
7	SP	When you interacting with NAO physiotherapist I felt like talking to a real Person?		No
8	PU	Do you think the robot is useful to be used in hospitals?	Yes	
9	PU	Do you think the robot can help doctors with many things?	Yes	
10	PU	Do you think using a robot in the performance of physiotherapist exercises would improve the patient's condition quickly		No

Patient Response:

The questionnaire handed over to the patient after the session. For both sessions, the patient responses were too similar. His overall opinion was positive and he liked the idea of having the robot as an assistant. The patient communication showed that the patient enjoyed interaction with and feedback from the robot. The patient is suffering from multiple physical injuries, So he stated that robot couldn't improve his health condition alone without the physiotherapist's advice. Further, the patient suggested developing the robot to perform knee exercises, considering the robot flexibility in knees joints, and that he is willing to try these knees exercises.

#	Code	Questions	Yes	No
1	PENJ	Do you enjoy doing exercises with NAO physiotherapist?	Yes	
2	PENJ	Do you find NAO physiotherapist boring?		No
3	PENJ	Do you find interacting with NAO physiotherapist is entertaining?	Yes	
4	PEO U	do you find it easy to get a robot for physiotherapist exercise to do what you want it to do?	Yes	
5	PEO U	Do you find interaction with NAO physiotherapist is clear and understandable?	Yes	
6	PEO U	Do you find it flexible dealing with a robot for physiotherapist exercise?	Yes	
7	ITU	Are you willing to repeat again the experience for using the NAO physiotherapist robot?	Yes	
8	SP	When interacting with NAO physiotherapist I felt like talking to a real Person?	Yes	
9	SP	Did you thought at some point as if the robot was really looking at your face?	Yes	
10	PU	Do you think using any robot would be useful for you?	Yes	
11	PU	Do you think that using a robot can help you with doing many things?	Yes	
12	PU	Do you think using a robot for exercise would enable you to improve and maintain your health more quickly?		No

4.2. Results observation

Assessing the patient is essential to catch his first reaction as well as his acceptance and motivation throughout the session. The criteria in TAM mode were evaluated from 0 to 4, 4 is excellent and 0 is considered unacceptable. Table 1 shows the patient assessment through the two sessions.

The patient did not express any noticed first reaction in both sessions but later he exchanged "hello" with the robot. The patient readiness to start the exercise was good as he did not hesitate and started to follow the robot commands immediately. The performance of the patient for the exercises by following the robot was good. Also the transition from exercise #1 to exercise #2 was good. The patient's ability to understand robot's instructions are considered very excellent. The patient greatly enjoyed performing the exercises with the robot. The patient's reaction is considered good and he was enjoying while listening to encouragement words from the robot. The patient was ready to end the exercise session and found the closing very excellent

Table 1. Patient Average assessment through sessions.

patient Assessment Question	Session Steps	Unacceptable	Poor	Fair	Good	Excellent
	Robot Entrance and Welcoming	0 pts	1 pts	2 pts	3 pts	4 pts
patient first reaction toward robot (smile, laugh...)			1			
patient impress				2		
patient replay (Hello) to robot					3	
patient ready to take the position for exercise					3	
patient ready to start exercise						4
	First Exercise					
patient can hear/ understand Robot speech						4
patient follow robot exercise					3	
patient enjoy performing exercise						4
patient accept break time						4
	Second Exercise					
patient motivate to do the 2nd exercise					3	
patient reaction toward robot’s encouragement phrases					3	
	Third Session					
patient motivate to do the 3nd exercise					3	
patient readiness to continue with robot						4
patient's reaction towered closing the session						4
patient's reaction toward leave						4

taking the robot						

5. CONCLUSIONS

The compressible discs that create a separation between the interlocking bones of the spine may get worn out and become inactive. This condition called Disc Disease Diagnosis DDD. However, technological innovations have made it possible to mitigate the pain for DDD patients. Robots also can be utilized to maintain and assess in treating patients suffering from degenerative disc diseases. This research aims to address patients acceptance to physiotherapist robot that can train and motivate the patient during the session under physiotherapists observation. The study followed the methodology of evaluation tools that can be used to assess the robot and the provided exercises. The research included an implementation for a set of exercises suitable for DDD on Nao robot. Nao robot performed a collection of five scenarios including an initiating scenario, exercises scenarios, and a finalizing scenario. The scenarios were designed to get patient's approval by providing breaks between exercises according to the patient's desire. Also, the robot was programmed to interact vocally with the patient during the whole session to motivate the patient to continue the exercises and encourage them to enjoy the session.

Two live therapy experiments applied with the patient. Two questionnaires handed to the physiotherapist and patient. The questionnaires designed to evaluate patient's acceptance and motivation according to technology acceptance model (TAM). The results overall were encouraging as both the patient and the physiotherapist approved that the robot provide motivation. Also, the

patient accepted the robot as an assistant and suggested to apply future sessions with the robot which indicates his overall acceptance of the physiotherapist robot.

6. ACKNOWLEDGMENT

The authors would like to thank Dr. Fayez Alshehri from National Guard Health Affairs (NGHA) and who provided us with guidance and insight that greatly assisted the research. We would also like to show our gratitude to Dr.Tibor boka from National Guard Health Affairs (NGHA) for collaboration and facilitating the experiments environment.

Appendix A

The appendix is an optional section that can contain details and data supplemental to the main text. For example, explanations of experimental details that would disrupt the flow of the main text, but nonetheless remain crucial to understanding and reproducing the research shown; figures of replicates for experiments of which representative data is shown in the main text can be added here if brief, or as Supplementary data. Mathematical proofs of results not central to the paper can be added as an appendix.

Appendix B

All appendix sections must be cited in the main text. In the appendixes, Figures, Tables, etc. should be labeled starting with 'A', e.g., Figure A1, Figure A2, etc.

7. REFERENCES

[1] L. Lewis, T. Metzler, and L. Cook, "Evaluating Human-Robot Interaction Using a Robot Exercise Instructor at a Senior Living Community," in International Conference on Intelligent Robotics and Applications, 2016, pp. 15-25: Springer.

[2] A Patient's Guide to Degenerative DiscDisease. Available: http://www.umm.edu/programs/spine/health/guides/degenerative-disc-disease

[3] G. B. Andersson, H. Svensson, and A. OdÉn, "The intensity of work recovery in low back pain," Spine, vol. 8, no. 8, pp. 880-884, 1983.

[4] H. B. Bressler, W. J. Keyes, P. A. Rochon, and E. Badley, "The prevalence of low back pain in the elderly: a systematic review of the literature," Spine, vol. 24, no. 17, p. 1813, 1999.

[5] (2016, 4 May). Low Back Pain Information for patients. Available: http://www.ouh.nhs.uk/patient-guide/leaflets/files/5712Plowbackpain.pdf

[6] Y. S. Morsi, Optimizing Assistive Technologies for Aging Populations. IGI Global, 2015.

[7] H. Kuo et al., "Age and gender factors in user acceptance of healthcare robots," in Robot and Human Interactive Communication, 2009.

RO-MAN 2009. The 18th IEEE International Symposium on, 2009, pp. 214-219: IEEE.

[8] M. Fior, S. Nugent, T. N. Beran, A. Ramirez-Serrano, and R. Kuzyk, "Children's relationships with robots: robot is child's new friend," 2010.

[9] Burgar CG, Lum PS, Shor PC, Van der Loos HM, "Development of robots for rehabilitation therapy: The Palo Alto VA/Stanford experience," Journal of rehabilitation research and development, 2000 Nov 1;37(6):663-74.

[10] Fazekas, G., Horvath, M., Troznai, T., & Toth, A. (2007). Robot-mediated upper limb physiotherapy for elderlys with spastic hemiparesis: a preliminary study. Journal of rehabilitation medicine, 39(7), 580-582.

[11] J. P. Vital, M. S. Couceiro, N. M. Rodrigues, C. M. Figueiredo, and N. M. Ferreira, "Fostering the NAO platform as an elderly care robot," in Serious Games and Applications for Health (SeGAH), 2013 IEEE 2nd International Conference on, 2013, pp. 1-5: IEEE.

[12] P. Gadde, H. Kharrazi, H. Patel and K. MacDorman, "Toward Monitoring and Increasing Exercise Adherence in Older Adults by Robotic Intervention: A Proof of Concept Study", Journal of Robotics, vol. 2011, p. 11, 2017.

[13] K. Wada, T. Shibata, T. Saito and K. Tanie, "Effects of robot-assisted activity for elderly people and nurses at a day service center", Proceedings of the IEEE 92.11, 2004, 1780-1788.

[14] S. Parsianmehr, S. Moosavian and A. Fakharian, "An experimental system identification modeling and robust control for NAO humanoid robot", Robotics and Mechatronics (ICROM), 2016 4th International Conference on. IEEE, 2016.

[15] G. Majgaard, "HUMANOID ROBOTS IN THE CLASSROOM." Iadis International Journal on Www/internet13.1, 2015.

[16] F. D. Davis, "A technology acceptance model for empirically testing new end-user information systems: Theory and results," Ph.D. dissertation, Massachusetts Institute of Technology, 1985.

[17] M. Heerink, "Exploring the influence of age, gender, education and computer experience on robot acceptance by older adults," in Proceedings of the 6th international conference on Human-robot interaction. ACM, 2011, pp. 147–148.

[18] M. Heerink, B. Kröse, V. Evers and B. Wielinga, "The influence of social presence on acceptance of a companion robot by older people", Journal of Physical Agents (JoPha), vol. 2, no. 2, pp. 33-40, 2008.

[19] T. Chen, T. Bhattacharjee, J. Beer, L. Ting, M. Hackney, W. Rogers and C. Kemp, "Older adults' acceptance of a robot for partner dance-based exercise", PLOS ONE, vol. 12, no. 10, p. e0182736, 2017.

[20] S. Shamsuddin, H. Yussof, S. Mohamed and F. Hanapiah, "Design and Ethical Concerns in Robotic Adjunct Therapy Protocols for Children with Autism", Procedia Computer Science 42, 2014.

[21] M. Heerink, B. Kröse, V. Evers and B. Wielinga, "Relating conversational expressiveness to social presence and acceptance of an assistive social robot", Virtual Reality, vol. 14, no. 1, pp. 77-84, 2009.

Article Citation:

Authors Name. **Banan Emad Alshahwan**. Implementing a Physiotherapy Robot to Assist Disc Disease Patient. AJR 2020; 1(1): 01-16.
DOI: https://doi.org/10.5281/zenodo.3938843