Humanoid Robot Integration in Rehabilitation of Musculoskeletal Conditions

Fayz S. Al-Shahry¹, Rayan F. Al-Shehri²

¹Assistant Professor COAMS, KSAU-HS, Consultant Rehab, KAMC, ²Engineering Student, KSU, Riyadh

Abstract

Robots find numerous applications in medical/health domains and are extensively used in commercial as well as domestic applications to support daily life activities. Human robot (HR) has widened their wings to be used in rehabilitation applications. Interest in robots that provide health care is growing as one of the upcoming fields of next generation. In this study we investigated the Robot -patient performance in physical rehabilitation. A group of musculoskeletal patients diagnosed with pain in muscles or joints or both, aged 20 to 65 years was chosen for the study. The robot was programmed to instruct and guide the patients for physical rehabilitation activities for three trials of 30 minute sessions on different days. The sessions involved interaction with a humanoid robot. Robot was programmed for a set of active exercises with a classified sequences that are time and motion managed. Verbal communication between the robot and patients allowed for re-start, stop, resume and replay functions. The whole performance was filmed and reviewed from the perspectives of the impact on the patient as well as the performance of the robot. The whole process was validated by performing the same procedure on a trial basis with healthy individuals to ensure the setup is operated smoothly. The performance of each variable was evaluated in three successive sessions. Evaluated functions include clarity, therapy sequence, interaction, voice, timing, independency, operation, technical performance and degree of freedom. Results were computed as percentages by an external assessor. Results demonstrated dynamic learning in the 1st and 2nd sessions which showed a remarkable improvement in the 3rd, 4th and 5th sessions. The overall average of the performance for the last 3 sessions was 91+%. Referring to this outcome, it could be concluded that the robot may have the potential to influence the physical therapy imitation. However, to establish the extent of this influence affirmatively, a bigger sample will be needed with a wider variety of patients.

Keywords: Humanoidrobot, interaction, integration, rehabilitation, musculoskeletal.

Introduction

Robots are being designed to complement human skill sets, reduce workload and enable professionals to focus on more important activities that have a greater impact on patient care delivery. As this technology advances and becomes more affordable, we can expect more health care institutions to adopt robotics.

Robots are still not a replacement for human interaction. Hospital operations are complex and involve uncertainty. Robots are good for performing repetitive tasks and tracking data, but this technology should only be used to make the clinicians’ workflow easier so that they may focus on the most critical part of their jobs, which is caring for patients.

Advanced humanoid robots are employed in a variety of applications in medical/health domains and are also used extensively in commercial establishments as well as in the home support for daily life activities. Beyond the traditional scope, robot can be engaged in the rehabilitation process and it is poised to become one of the most important technological innovations of the 21st century. Literature showed specific uses with elderly patients and some pediatric applications.¹,²

In this article, we offer a trial study on the possible uses of robots in rehabilitation, particularly in the management of musculoskeletal conditions.

Human Robot (HR) has widened their wings to be used in rehabilitation. Interest in health care robots is
Some of the robotic technologies were designed to assist the user primarily through social rather than physical interaction. For example, a previous study has established Kindergarten Assistive Robotics (KAR) as a tool for learning and development for normal children in preschool education. KAR has increased children’s motivation and communication during the interaction. Robots have been successfully introduced into physical therapy and rehabilitation of children with disabilities. Thus, KAR is suggested to be applied for CP children. One of the studies involved KAR as a Robotics Agent Coach for CP motor Function (RAC CP FUN) which is designed to improve their motor functions and activities associated to daily living. Further, another study employed a mobile robot named “Neptune” and used a toy robot named “Cosmobot” and the derived results showed that robot can become a social mediator for learning. The results of a study that used Lego Mindstorms robots for CP children’s play activities demonstrated that the children reacted positively toward the robots, while some children increased their attention span and could be better engaged when they used the robots. However, most explored robotic systems earlier were mainly in the form of toys, and not in humanoid form. Thus, this study is designed to use a humanoid robot to instruct patients in physical therapy sessions with musculoskeletal problems. An expert software programmer and a physiotherapist jointly developed the therapy program. Details of the therapy were tailored specifically to meet the needed conditions, interact with the patients, with the mode and specification capable of offering several options.

Methodology

The intended group is a set of musculoskeletal patients diagnosed and referred for P.T clinic. A strengthening exercise was prescribed and endorsed by a licensed physiotherapist specialized in the musculoskeletal disorders. This particular group was for improving the back strength, with age range between 20 to 65 years. Other inclusion criteria were no physical or mental disability, no hearing and vision deficiency, and a cognitive ability to follow simple commands in English. Signed informed consent was obtained from the participants. Five trials, each of 30 minutes session were performed on different days. The sessions involved interaction with humanoid robot. The experiment protocol was approved by the Occupational Therapy Association Research Board. The robot was programmed for a set of active exercises with a classified sequence managed in time and motion. Verbal communication between the robot and patients allowed re-start, stop, resume and replay functions. The robot was equipped with 4 cameras and programmed to take photos of the patient’s face and voice print to enable individual recognition in order to recall the personal therapy program and update the patient information at the end of the session. The whole performance was filmed and reviewed from the perspectives of both the patient and robot. The whole process was validated by performing the same procedure on a trial basis with healthy individuals to ensure the setup is operated smoothly.

Patients were educated about the robot and the study aim. An introduction session was made to familiarize the group (robot, patient, operator and the assessor) with the study methodology. The study was conducted in a simple gym, with the exercise mat laid on the floor for the patients and the NAO was placed on the non-slippery floor. The performance assessment will use met partially me or not met.

NAO has 23 degrees of freedom: 2 degrees of freedom for head, 4 degrees of freedom for each arm, 1 degree of freedom for pelvis, and 5 degrees of freedom for each leg.

Result

The aim of this robotic-patients application is to instruct patients with musculoskeletal problems for several pre-structured and programmed exercises. The overall aim is to measure several factors that govern the robot-patient performance, e.g. clarity, sequence, interaction, voice, timing, independency, operation, technical performance, and degree of freedom. The assessment is expressed by% of excellence for the three times and then the% average is gathered for all patients. The total for each parameter in each session and the total for the five patients for each session is presented. The data in the table below is the grand total for the three sessions for five patients and expressed in %.
Table 1: The data here is representing the% of performance of each item. The performance of the last three visits are averaged in the last column and the grand average for the overall performance (91+) is also presented. The 1st and 2nd sessions were considered as learning sessions.

<table>
<thead>
<tr>
<th>Item</th>
<th>Trial sessions</th>
<th>3rd session</th>
<th>4th session</th>
<th>5th session</th>
<th>Average %</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1st session</td>
<td>2nd session</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Clarity</td>
<td>50%</td>
<td>70%</td>
<td>90%</td>
<td>95%</td>
<td>95%</td>
</tr>
<tr>
<td>Therapy sequences</td>
<td>30%</td>
<td>60%</td>
<td>90%</td>
<td>90%</td>
<td>100%</td>
</tr>
<tr>
<td>Interaction</td>
<td>20%</td>
<td>60%</td>
<td>95%</td>
<td>95%</td>
<td>95%</td>
</tr>
<tr>
<td>Voice</td>
<td>70%</td>
<td>70%</td>
<td>80%</td>
<td>90%</td>
<td>95%</td>
</tr>
<tr>
<td>Timing</td>
<td>40%</td>
<td>60%</td>
<td>100</td>
<td>95%</td>
<td>100%</td>
</tr>
<tr>
<td>Independency.</td>
<td>60%</td>
<td>80%</td>
<td>80%</td>
<td>90%</td>
<td>90%</td>
</tr>
<tr>
<td>Operation</td>
<td>70%</td>
<td>90%</td>
<td>90%</td>
<td>90%</td>
<td>95%</td>
</tr>
<tr>
<td>Technical performance</td>
<td>90%</td>
<td>90%</td>
<td>90%</td>
<td>90%</td>
<td>95%</td>
</tr>
</tbody>
</table>

Consequently, there are few points to be highlighted and discussed. The data presented represent the external assessor evaluation of the performance. It is clear that the 1st session is a learning step which shows low levels of performance. Second session showed remarkable improvement and a continuous improvement is recognized in the 3rd session. The overall impression is supporting the fast and reliable interaction integration. The total performance related to the robot therapy assignment is seen as highly satisfactory and manageable with the patient acceptance of the whole process.

Fig 1: Shows the representation of various performance parameters. This indicates the average percentage of the last three sessions.

Fig 2: A, and B, The robot is oppositely facing the patient to assure face to face communication, both in lying position. The robot NAO asks the patient to imitate each movement. NAO starts to perform the exercise and patient is expected to follow, patients should match the time in a steady sequence and follow and repeat for several times matching the robot command. The robot is watching the patient through the cameras and has the capability to stop, rectify, adjust and resume.
Discussion

The set up of this robot rehab program was made to serve patients at the clinic or at home. The overall performance was great, smooth and relatively reliable in this small trial group. This work encourages interest groups to proceed with robot rehab therapy. The available data from this trial study showed the robot-patient performance and the technical performance as well as the operational performance. The imitation of movement simultaneously with the robot confirmed the possibility of independent execution of serial therapy program in the rehab clinic or at home particularly for chronic conditions. The total percentages core of the last three sessions was around 92. However, further optimization of the robot programming and proper prescription of exercise program and careful selection of patients could make the work performance highly efficient. Each of the eight parameters of this study were assessed in five different sessions. These parameters are believed to be the most important factors to govern the implementation. Optimizing them will enable the robot to work independently with the patients at the clinic or at the home and this will enable to personalize this technology and the outcomes\(^7,8\) are in line with this result.

It is worth saying that the interaction was very successful and the options of stop, resume, restart were used many times to cater to patients’ requests, and this was considered healthy. The clarity of steps and voice level was perfect and the patient’s follow-up on sequence was also maintained to a high level. Progressing with time is a notable and clear indicator which means that the patient-robot relation is supporting the level of confidence of the patient as well as the therapist, and this matches earlier reported outcomes\(^13\). This is an improvement of the technology with a friendly perspective. The overall satisfaction of the patient and the acceptance were high and very promising. The grand total performance of all eight parameters was very high (almost 92%) which substantiates its applicability in the clinical robotic industry in line with the\(^16,17,18\).

This article is meant to cover solutions at different stages of applications. Thereafter it is up to the developer to commercially make it ready and available in the market or to look to some alternative or to go for more phases of research and experimentation. The existing data provides examples and pointers to proceed to clinical applications and other major ingredients for the success of these applications as well as the main issues surrounding their adoption for a wide range of everyday physiotherapy use are to be developed further. We have examined how robotics could partially fill in some of the identified gaps in current telehealth-care through internet connectivity since the robot is equipped with 4 Cameras and can recognize individuals by face and by voice tone. Introducing a tele control can pave the way for program modification and alteration based on instantaneous robot-patient interaction and would bring in a possibility of remote sharing with a third party or more in audio-visual mode.

We conclude with a brief glimpse at a couple of emerging developments and promising applications in
this field that are expected to play important roles in the future. Readers should note that this paper is intended to be read mainly by non-roboticists, with little or no background in the field. Specifically, the paper is meant to ignite the interests of conventional health informatics and telemedicine/telehealthcare specialists and clinicians, physiotherapists and rehabilitation professionals into such emerging possibilities. It would also be of interest to experts in robotics who are interested in its potential applications, especially about how robotics may help users in the healthcare and social care sectors. This also my facilitate investments and businesses in the long-term to commercialize use of robotics in health sectors, both in health care centers and in homes.

Conclusion/Recommendations

This trial outcome is highly supportive to the use of robot in rehabilitation of patients. More focus may be needed to improve the friendly interaction and flexible sequence between exercises. Logistic support may be included e.g. refreshment time, rest, short breaks may be considered upon patient request.

There is also a need to address some challenges encountered in the set up. The degree of freedom for all joints was of acceptable level except the pelvic rotation. There is a need to improve on the robustness of the pelvic movement.

The issue of the NAO system getting heated up during the performance causing an interruption in the session needs to be investigated and resolved.

Based on this trial, it is recommended that this work be continued with a larger sample and varying conditions to ensure consistent approach and reliable outcomes.

Conflict of Interest: Nil

Source of Funding: Self

Ethical Clearance: Attached

References

12. Amy J. Brisben, A.D. L., Charlotte S. Safos,


