A robot instructor for aging population

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***Abstract*—Sarcopenia is an age-related pathology, which causes the loss of skeletal muscle tone, mass and strength. To prevent the onset of Sarcopenia and to contrast its effects, it is important to perform physical exercises. One of the main problem is to motivate elderly people to start a training routine. The primary aim of this study targeted this problem. We designed a platform where the humanoid robot Pepper guided a group of subjects to perform a set of physical exercises specifically designed to contrast Sarcopenia. The robot illustrated, demonstrated, and then performed the exercises simultaneously with the group. With an additional external camera Pepper controlled in real time the execution of the exercises, encouraging participants who slowed down or did not complete all the movements. Moreover, the processing offline of the recorded data allowed estimating individual performance of 8 subjects. We evaluated participants' satisfaction with a questionnaire that reported a high degree of satisfaction for the robot-guided training. Also, all participants followed the robot respecting the correct timing of the exercises.**

Keywords— Humanoid Robot; Therapy and Rehabilitation; Assistive Robotics; Sarcopenia

I. Introduction

Today there is an increase in the disabling physical pathologies that occur in correlation with aging [1]. It is therefore necessary to investigate solutions that can solve and prevent the onset of certain diseases related to physical ageing. This will indirectly reduce overcrowding in health care and the associated costs.

Sarcopenia is one of these age-related pathology; it causes a progressive and generalized loss of muscle mass accompanied by a decline in muscle strength and performance [2]. Since a sedentary lifestyle is a risk factor, the best treatment is the one that involves physical activity [3].

The research and implementation of innovative techniques for prevention and therapeutic intervention are current challenges due to the increasing number of people affected by Sarcopenia and related complications and disabilities. Some of these techniques provide online platforms that, through games and virtual avatar, show which exercises to perform (e.g. PAMAP, Physical Activity Monitoring for Ageing People [4]). Others use robotic assistants and rehabilitators to guide in presence, the training session by showing and explaining the exercises (e.g. ROBOPHILLO [5] and PHAROS, PHysical Assistant RObot System [6]).

The use of a virtual avatar makes people feel less involved because of a pure virtual and not physical presence; but at the same time, although the use of humanoid robots happens in presence, it is not true that any humanoid robot is always able to guarantee this high level of involvement. In fact, the size of the robot and its external appearance make a significant contribution [7]. Given this background, we developed and tested a robotic system that allows group session of physical activity for people with Sarcopenia, ensuring an engaging training.

The platform is based on the humanoid robot Pepper as teacher and exercise demonstrator. The platform monitors each subjects' performance through the integration of an external camera.

II. Platform Architecture

The platform we developed includes the humanoid robot Pepper, an external camera and screen.

To guarantee a high level of attention and interaction from subjects, we decided to use Pepper, who provides detailed instructions on how to execute the exercises and performs the exercises simultaneously with the group thanks to its anthropomorphic upper limbs.

The wider screen helps the robot to provide clear graphical instructions on how to correctly perform the exercises, which involve the lower limbs, by displaying demonstrative video of experienced physical therapists. Moreover, the robot gives indications about the rhythm and provides verbal explanations and the video is only a support.

The additional camera records each exercise in a single video. The analysis of each video provides on-line and off-line information about how each subject performs the exercise. Using the former information, the robot checks in real time that all participants fully perform all the required exercises and encourages the participants that stop or slow down the execution of the protocol. The off-line elaboration of the video recorded during the session provides participants with feedback about the quality of execution, highlighting the exercises, the specific movement and posture to improve.

III. Protocol and Subjects

The protocol aims at preventing and contrasting Sarcopenia and it was developed in collaboration with medical doctors and physiotherapists of the Geriatric, Orthogeriatric and Rehabilitation (CUROGE) department of the Galliera Hospital.

Two types of exercises are included in the protocol: warming-up and strengthening exercises.
In details, some exercises are performed with anklets or hand weights of 1kg, some while standing, and others while sitting. The clinical team selected the rhythms and the pauses for each exercise to maximize the efficacy of the protocol without incurring in unnecessary and risky efforts.

8 participants divided in 2 groups (G1, naïve about the exercises, and G2, physiotherapists, aware of the proposed exercises but not involved in the design of the experiment). Inclusion criteria for both groups were being in good health without known history of neurological disease, injury or cognitive disability.

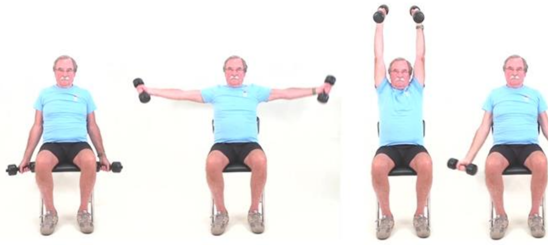

Figure 1. Example of exercise

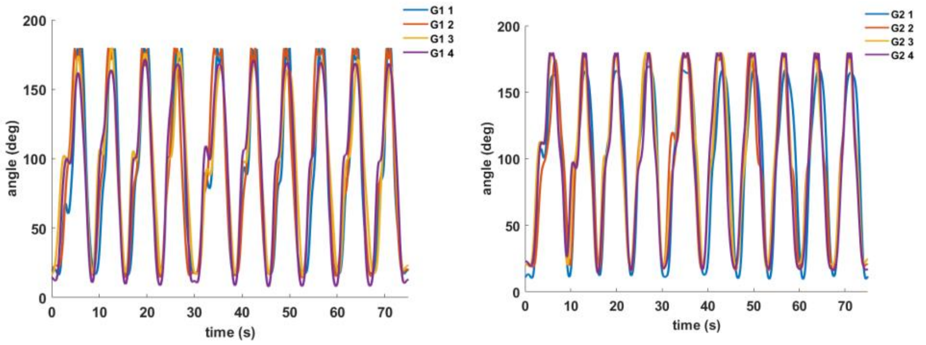

Figure 2. Sholuder angle for all the subjects in each group during the exercise of reinforcement of the upper limbs.

IV. Preliminary test

During each exercise the stream video from the camera sampled at 30fps, was on-line analyzed with OpenPose [8] to detect key points on the body of each participant. This information, given as feedback to Pepper, allowed an on-line evaluation of each participant's performance in terms of percentage of correct repetitions of the required movements.

The stream videos were also saved to verify offline that subjects performed at the best of their abilities the required movements while maintaining the correct body posture.

For each exercise we computed: the number of movements performed; the symmetry between left and right movements; the range of movement of the more relevant joints and the synchronization. This last parameter allows us to check whether participants are following the instructions and the rhythm given by the robot.

We report the results of a single exercise, to show the feasibility of this type of analysis.

We focused, as example, on exercise "reinforcement of the upper limbs" (Fig. 1). In this exercise participants were sitting on a chair and holding in the hand weights of 1kg. In the starting position, their arms were straight along the sides of the body, with the hands pointing toward the ground (notice that the presence of the chair did not allow to have 0 degrees of abduction). Then participants abducted their shoulders, rising both arms sideways and then bringing at the same height of the shoulders (90 degrees abduction), without changing their elbow angle. They paused in this position and then continued the movement until they reached 180 degrees of abduction and went back in the starting position. All participants completed this exercise, performing all the required movement repetitions.

At the end of the session to evaluate the level of satisfaction of the participants, a short survey was proposed.

V. Results and discussion

The analysis of the shoulder joint movements reveled that all subjects, following the robot, were able to move synchronously (Fig. 2) i.e. their movements were highly correlated with negligible delays among participants. This suggests that all subjects followed the timing requested from Pepper.

With a multiple-choice questionnaire, we found that both groups appreciated the robot-based training session, in particular all participants unanimously rated the robot-driven training as useful and satisfactory (100%, 8/8), everyone felt better immediately afterwards and appreciated the proposed protocol.

Conclusion

The features of the robot and its shape proved to be suitable for the study: people found Pepper an excellent trainer, able to show them all the exercises in a very understandable way and guiding them to complete the protocol maintaining the correct pace.

The results obtained by the whole platform, both on-line and off-line, are good indicators to quantitatively assess movement performance.

In conclusion, the entire platform is functional for the purposes of the study, i.e. to guide and monitor group of people during exercise sessions and to obtain good interaction, engagement and attention from the users.

What is reported in this paper refers to the full paper presented at the Ro-man 2020 conference, where the full result are reported.

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