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Kinect-based integrated physiotherapy mentor application for shoulder damage

Burakhan Çubukçu [a], Uğur Yüzgeç [a,*], Ahu Zileli [b], Raif Zileli [c]

[a] Department of Computer Engineering, Bilecik Seyh Edebali University, 11210, Bilecik, Turkey
[b] Department of Physical Medicine and Rehabilitation, Bilecik State Hospital, Bilecik, Turkey
[c] School of Health, Bilecik Seyh Edebali University, 11210, Bilecik, Turkey

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ABSTRACT

With the increasing rate of disabled people in the world, the number of people in need of physiotherapy is increasing. Most of the disabled persons with shoulder damaged should do physiotherapy exercises. The telerehabilitation systems using developed technologies have advantages over conventional physiotherapy methods. Such systems have the potential to improve communication between patients and physiotherapists. They also allow for easier information and medical data sharing. In this study, a telerehabilitation system based on Kinect Sensor (Kinect 2) was developed to observe and evaluate shoulder damaged patient exercises by using the Kinect skeletal monitoring feature. The proposed system consists of two basic components: the web application that enables the communication between patients and physiotherapists, allows the physiotherapist to observe/update patient exercise data, patients information, and the console application which enables the patients to perform their exercises correctly. This console app was developed for patients with shoulder damage. Abduction, flexion, internal rotation, external rotation, extension exercises can be performed correctly thanks to the developed application. The proposed system was evaluated in Bilecik State Hospital for 29 shoulder damaged volunteers. 14 of the volunteers were treated with the conventional methods and 15 of them were treated with the proposed system. The recovery of the volunteers was analyzed for each intragroup and intergroup comparison was made. Statistically, significant decreases were observed in the limitations of the patients treated with the proposed system. For abduction, flexion, internal rotation, and external rotation exercises, the Kinect-based physiotherapy mentor application was more successful than conventional method, while all volunteers treated by the proposed method had no limitations in extension exercise. As a result, the Kinect-based physiotherapy mentor application can be used as an alternative telerehabilitation method for patients with shoulder damaged.

1. Introduction

World Health Organization (WHO) media center report shows that there are more than one billion people with some disabilities [1]. Some of these people need rehabilitation for a while, while others need rehabilitation throughout their lives. Patients who have to do physiotherapy exercises face some problems during the treatment process. The exercises must be performed correctly in order to complete the treatment process in the best way. The researches show that patients exercising alone can only perform 31% of the exercises correctly. 65% of the patients do not understand whether they can do the exercises correctly [2–5].

With the developing technology, different solutions to these problems in the field of physical therapy are produced. The term of telerehabilitation can be described as the provision of rehabilitation services via the internet and telecommunication networks. [6]. Research has shown that patients can do their exercises using telerehabilitation apps without the physiotherapist at home [7]. In addition, the exercises with telerehabilitation are as effective as done by traditional rehabilitation methods. Thanks to telerehabilitation; Patients make sure that they do the exercises correctly and the rate of patients doing the exercises correctly increases. Therefore, while the recovery rates of the patients increase, the recovery times decrease. These correct and effective exercises can be repeated without going to the hospital and the data of all exercises of the patients can be recorded. Nowadays, 3D motion capture systems are used in telerehabilitation studies. They provide excellent accuracy and reliability. However, these systems are very expensive and require large spaces for use. A motion-sensing device (Kinect sensor) produced by Microsoft,

* Corresponding author.
E-mail addresses: burakhan.cubukcu@bilecik.edu.tr (B. Çubukçu), ugur.yuzgec@bilecik.edu.tr (U. Yüzgeç), ahukaratas@hotmail.com (A. Zileli), raif.zileli@bilecik.edu.tr (R. Zileli).

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is used as an alternative to these systems. Kinect sensor is a less expensive system than 3D motion capture systems and this system is portable easily, the required working area is smaller than 3D motion capture systems [8–11].

First Kinect 360 (Kinect 1) in 2010, then Kinect ONE (Kinect 2) was released in 2014. Kinect 2 includes a Time-of-Flight (ToF) camera and determines the depth by measuring the time delay between the emitted light signal from the camera to the object and the received signal back from the object to the camera [12]. By Kinect 2 skeletal joint monitoring features, the coordinate information of 25 points on the human skeleton can be obtained, so Kinect is a useful tool for telerehabilitation studies. There are many validity and reliability tests in the literature to find out whether the skeletal data detected by Kinect 2 are sufficiently accurate for medical evaluation. In these studies, Kinect 2 is compared with goniometers or 3D motion systems to test Kinect validity. The reliability of Kinect was tested with different people at different times by test-retest studies. According to the test results, Kinect 2 can make accurate and reliable measurements enough to be used in rehabilitation [13–22]. When Kinect-based telerehabilitation studies are examined in the literature, it is seen that the studies are mostly aimed at the daily rehabilitation exercises of elderly people. Studies for people with a specific disease other than daily rehabilitation are mostly aimed at the treatment of very severe diseases such as Parkinson's and stroke. Exercises that patients with severe diseases can do are very easy to do like elderly people's daily exercises. Apart from these, there are telerehabilitation studies for injuries such as shoulder injury and anterior cruciate ligament injury. The main purpose of some studies in the field of telerehabilitation is to provide communication between the doctor and the patient, there are studies that suggest teleconferences for this. The main purpose of some studies is to make the patient exercise and some of them do not make any measurements. Some of these types of studies aim to reduce the boring of rehabilitation exercises rather than observing the patient's condition by making patients exercise game-based. When the studies in the field of telerehabilitation in the literature are examined, it is seen that Kinect sensor is used frequently [23–28].

The pathologies causing movement loss in the shoulder joint are impingement syndrome, rotator cuff tendinopathy, shoulder instability and adhesive capsulitis [29]. There are five basic motions, such as abduction, flexion, extension, internal and external rotation movements in the shoulder joint [30]. In this study, an integrated physiotherapy mentor application (PhyMen) was developed by using Kinect 2 to help patients with shoulder damage during the rehabilitation process. This system was tested on the patients with shoulder damage in Bilecik State Hospital (Bilecik - Turkey). The proposed mentor application consists of two basic parts: the web application that provides interaction between the patients and the physiotherapists, Improved Shoulder Physiotherapy Application (ISPA) which enables the patients to exercise. In the study of Cubukcu and his friends, the validity and reliability analysis of the ISPA system was performed and it was shown that it can be used as an alternative measurement method for shoulder patients by comparison with classical methods (goniometer and digital goniometer). According to this study that tests the validity and reliability of ISPA, the reliability test results show that Kinect 2 based measurement system is very good for abduction, flexion, internal rotation, external rotation poses, and has good reliability for extension pose. In the 95% limits of agreement (LOA) results of all exercises, it was observed that ISPA gives closer results to the digital goniometer than the clinical goniometer. According to the Bland–Altman analysis results, it is evident that the proposed Kinect 2 based shoulder motion measurement system is an alternative and effective method in comparison with both of the goniometers [31].

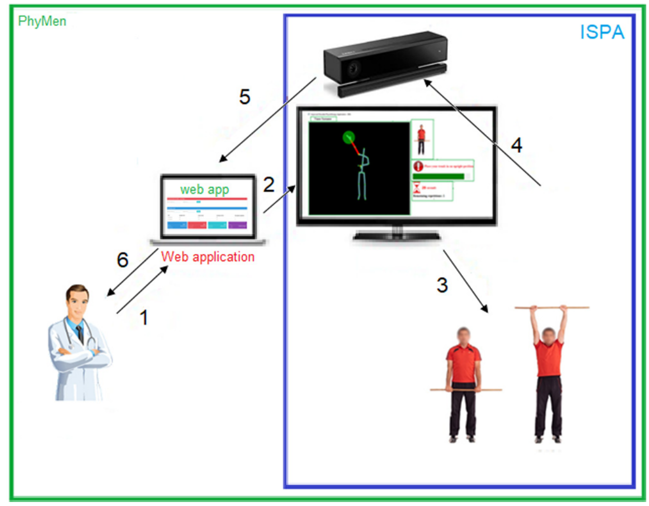

Fig. 1. Integrated physiotherapy mentor application.

In this study, 29 volunteers were divided into two groups, one group was treated with traditional method and one group was treated with the proposed system. For the volunteers in the group treated by the proposed system, their limitations were reduced from 10.65% to 30.42%, while the limitation values of other volunteers in the group treated by the traditional method were reduced from 9.52% to 13.37%.

The rest of this paper is organized as follows: In Section 2, the information about the proposed PhyMen system is given. Section 3 introduces the participant information, test procedure and statistical analysis about hospital tests on volunteers. Results and discussion of tests are given in Section 4. In the last section, conclusion and the future works are presented.

2. Integrated physiotherapy mentor application

By the mentor application developed, it is aimed to make the shoulder physiotherapy exercises correct and effective, to record the data formed during the treatment process, to provide instant information to the physiotherapists about the treatment process of the patients and to allow the physiotherapists to make changes in the treatment of the patients.

PhyMen system consists of two main components: the first is the ISPA, which enables patients doing the exercise correctly, and the second is the web application where the physical therapist can observe and make changes to the patient's treatment process. Fig. 1 shows the general diagram about the integrated physiotherapy mentor application.

The arrows 1 and 6 shown in this figure show the two-way communication between the physiotherapist and the server with the web interface. Similarly, arrows 2 and 5 indicate the server's communication with ISPA, arrows 3 and 4 show the patient's interaction with ISPA.

2.1. Improved Shoulder Physiotherapy Application (ISPA)

Improved Shoulder Physiotherapy Application (ISPA) was developed by using Kinect 2 and Kinect SDK 2.0. The ISPA was created in the Visual Studio environment and was designed as a Windows Presentation Form (WPF). The software was written using C # programming.

The main objectives of ISPA; to ensure that shoulder damaged patients perform their exercises correctly and to record these exercise data. ISPA provides the patients to perform abduction,

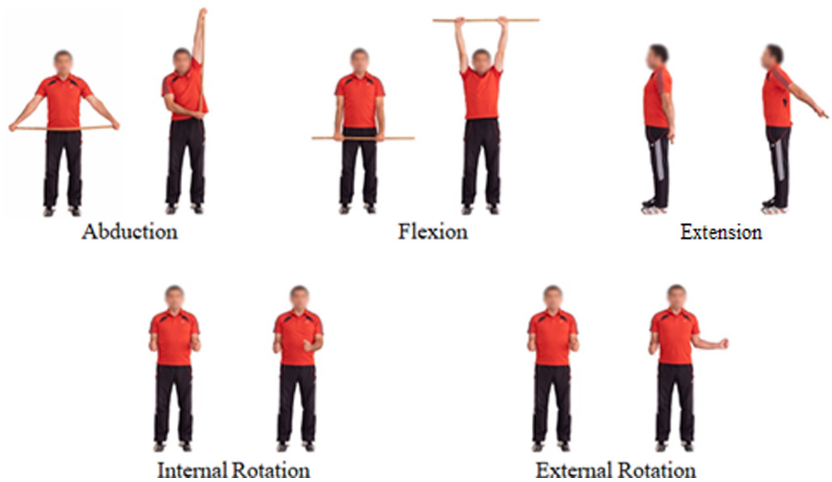

Fig. 2. Exercises for patients with shoulder damage.

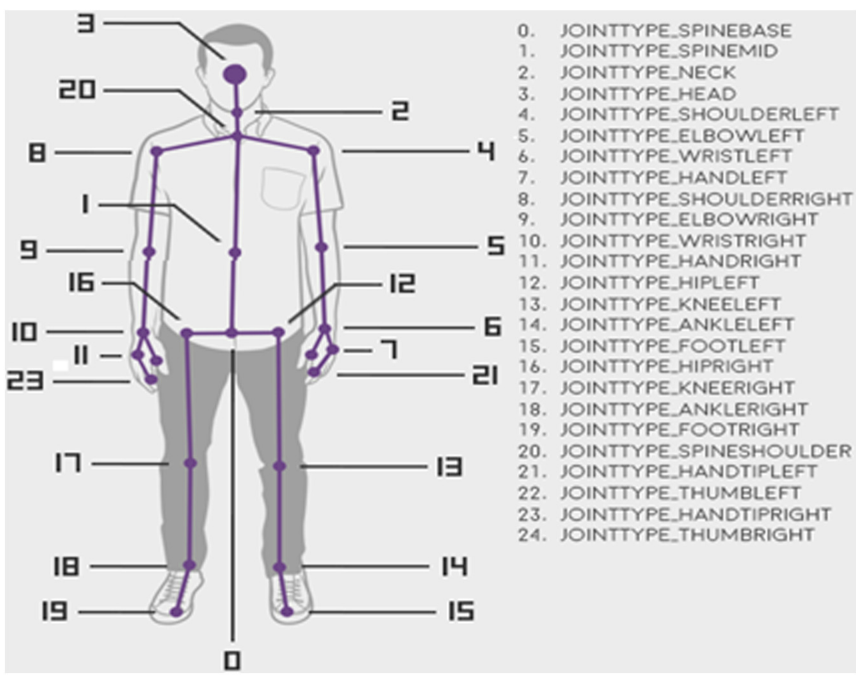

Fig. 3. Kinect 2 skeleton joints.

flexion, internal rotation, external rotation and extension exercises correctly (Fig. 2) and records the angle values made by the users in the exercises.

In order for the exercises to be performed, first of all, the coordinates of 25 points on the human skeleton are taken by Kinect 2 as shown in Fig. 3 and some points are used in the developed software for exercises. These 25 points cannot be enough for calculating the angle correctly in some exercises. As a result, new points are created which Kinect 2 does not provide, to find the most accurate angle values. For example, in order to calculate the angle value in the abduction exercise, skeletal points taken from Kinect 2 are not sufficient.

To form a new point; let us take $A\,(x_1, y_1, z_1)$, $B\,(x_2, y_2, z_2)$, $C\,(x_3, y_3, z_3)$ which are provided by Kinect 2, and $D\,(x_4, y_4, z_4) \in R^3$ is new point which is created. The point D is reconstructed to be $D\,(x_4, y_4, z_4) = (x_1, y_2, z_1)$ as shown in Fig. 4. The used points and calculated angles for five exercises in the ISPA are shown in Fig. 5. The hip left and hip right points provided by Kinect are not useful for abduction and flexion poses. Therefore, the left hip point (K – Abduction shown in Fig. 5.) is projected over the shoulder point and point B is formed for the left shoulder exercises. Then the newly created B point is used for abduction and flexion poses. All edge lengths of triangle (Fig. 4) which has points A, B, C where $A = (x_1, y_1, z_1)$, $B = (x_2, y_2, z_2)$, $C = (x_3, y_3, z_3) \in R^3$ are calculated by using Eqs. (1)–(3).

This process is repeated for all conditions and triangles used in exercises. Then, thanks to the Cosine Theorem (Eq. (4)), all angle values required for the exercises are calculated.

$$|AB| = c = \sqrt{(x_1 - x_2)^2 + (y_1 - y_2)^2 + (z_1 - z_2)^2} \tag{1}$$

$$|BC| = a = \sqrt{(x_2 - x_3)^2 + (y_2 - y_3)^2 + (z_2 - z_3)^2} \tag{2}$$

$$|AC| = b = \sqrt{(x_1 - x_3)^2 + (y_1 - y_3)^2 + (z_1 - z_3)^2} \tag{3}$$

$$\theta = \hat{C} = Arccos\left[\frac{a^2 + b^2 - c^2}{2ab}\right] \tag{4}$$

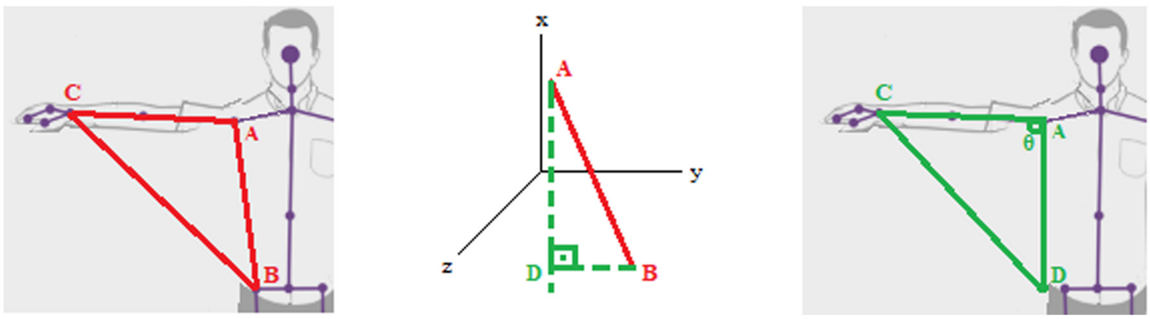

Fig. 4. Obtaining new point (D) from B point.

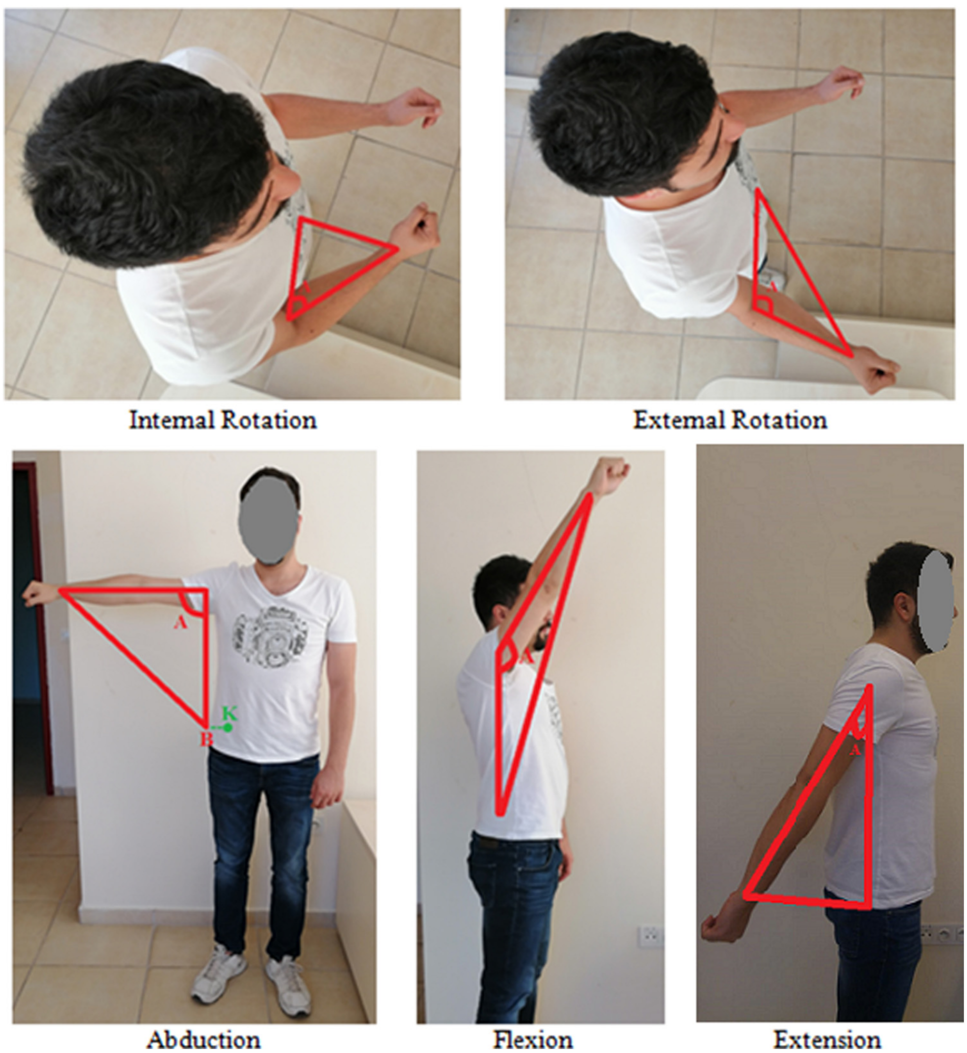

Fig. 5. Skeleton joints, triangles and angles used in exercises.

The ISPA enters the loop in Fig. 6 when the patient is in front of the camera and makes the angle calculations used in this loop as described above.

As shown in Fig. 6, the ISPA first checks the user (patient) information. Then, it takes the exercises, repetition numbers, target angle values which are belonging to the user from the database and updates the parameters to be used. ISPA divides the positions into two basic classes: starting position and exercise position. Some conditions are used to verify that the user is in the starting position and to ensure that the exercises are performed in the correct body positions. This allows the user to perform the exercises in the right body condition. If the user cannot provide a condition correctly, ISPA will lead the user with warnings. Limits and warnings used in ISPA are summarized in Table 1. The angles of the exercises performed by the user in the correct position are only calculated. The best angle value which the user has made within the specified time is recorded. If the user has reached the expected maximum angle in this period, the other exercise is passed without waiting for the completion of time.

These operations are performed as a standard procedure by changing the parameters for each user. As a result of this process,

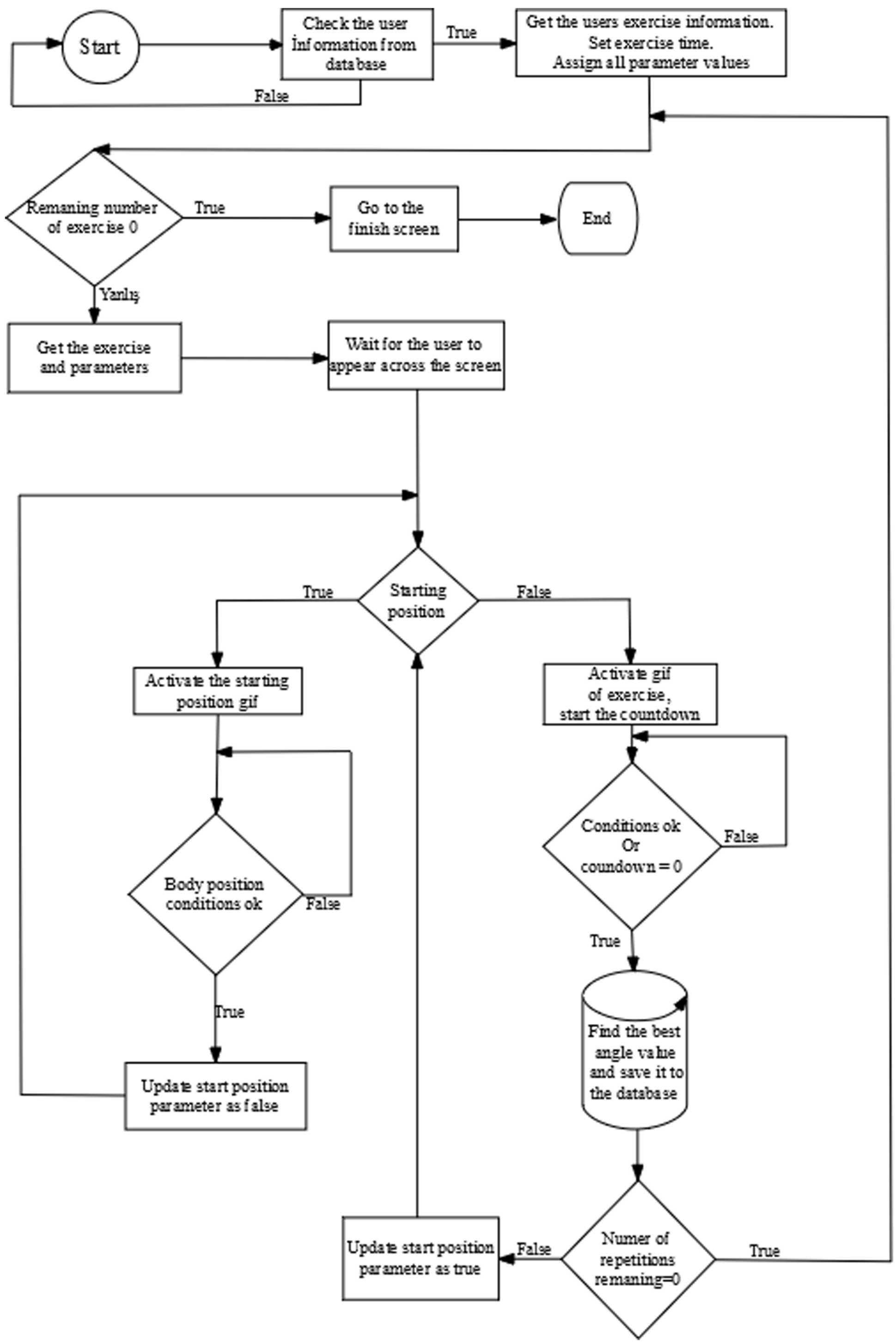

Fig. 6. Improved shoulder physiotherapy application flow chart.

ISPA provides the user with the opportunity to complete the exercises correctly and effectively. At the same time, it keeps a record of exercises and angle values and provides meaningful data for physiotherapists. Fig. 7 shows the ISPA's developed graphical user interface.

2.2. Web application of PhyMen

The web application was created with Model-View-Controller (MVC) architecture in Visual Studio environment using C # and JavaScript. The web page was designed using Metronic Template (v4). This web application was developed with the views and requests of the physiotherapists and doctors of Bilecik State Hospital.

The web application consists of two types of users: patient and physical therapist. On the advice page of the physiotherapists, only the exercise information and the doctor's contact information are available on the page that patients can view to avoid confusion. Patients can register themselves from the registration screen and log into the system when doctors confirm these registration requests.

Table 1
ISPA's conditions and warnings.

Conditions	Poses used	Warnings
The body is upright	All exercises All starting positions	Place your trunk in an upright position
Standing up	Abduction, flexion, extension exercises and starting positions	Please stand up
The distance between two hands is not close	Abduction, flexion, internal rotation, external rotation exercises and starting positions	Keep your hands apart
Hands on the side of the body	Abduction, flexion, extension exercises and starting positions	Bring your hands to your body
Hands perpendicular to the body	Internal rotation, external rotation exercises and starting positions	Keep your hands perpendicular to your body
Turning the body left / right	Extension exercise and starting position	Turn left/right to camera
Two shoulders parallel to each other	Abduction, flexion, extension exercises and starting positions	Bring your shoulders to the parallel position

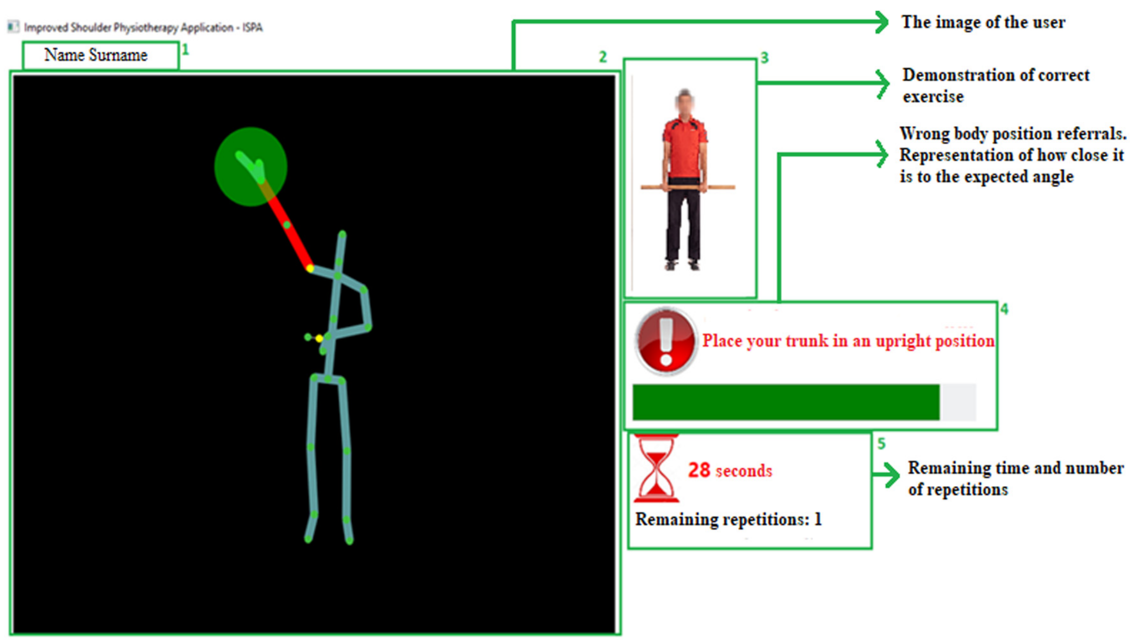

Fig. 7. ISPA's graphical user interface.

The physiotherapist users can access information, exercise assignment, patient data view/update pages. In the information page, physiotherapists can monitor their total number of patients, newly enrolled patients, patients who need to assign exercise, and patients who have not exercised in the last week. In the exercise assignment page, physiotherapists can enter the diagnoses of their patients and add/delete exercises. The patient data view/update page (Fig. 8) has been created with the request of the physiotherapists to perform all operations on a single page. In this page, the patient's information can be displayed, notes can be written about the patient and written notes can be displayed, the exercises assigned to the patient can be viewed, the patient's exercises and angle values can be displayed, the number of repeat exercises and the expected angle values from the patient can be updated. As shown in Fig. 8, the best, worst, average angle values and the number of exercises performed by the patient can be observed daily and during the treatment by physiotherapist. The patient has only one interface which is shown at last of Fig. 8 because physical therapists think that more information will confuse the patient.

3. Methods in hospital tests

3.1. Participants

29 shoulder physical therapy patients volunteered to participate in this study. 15 volunteers were included in the test group and 14 were included in the control group. The age, height and weight values of the participants are summarized in Table 2.

The mean age of men (n: 4) in the test group included in this study is 55.50 ± 17.06 years, average height is 175.50 ± 9.00 cm, weight average is 88.25 ± 16.09 kg and the mean age of women (n: 11) is 54.00 ± 8.35 years, mean height is 157.91 ± 6.19 cm and mean weight is 71.27 ± 9.26 kg. The mean age of the males in the control group (n: 6) is 52.83 ± 15.82 years, the mean height is 171.17 ± 11.05 cm, the mean weight is 79.17 ± 10.85 kg, and the mean age of women (n: 8) is 48.50 ± 8.05 years, the average height is 157.50 ± 4.21 cm, the mean body weight was 72.62 ± 13.78 kg. This study was approved by Bilecik Seyh Edebali University Ethics Committee (2017/04) and carried out in accordance with the Helsinki Declaration of the World Medical Association. Permissions were obtained for the implementation of the study at Bilecik State Hospital.

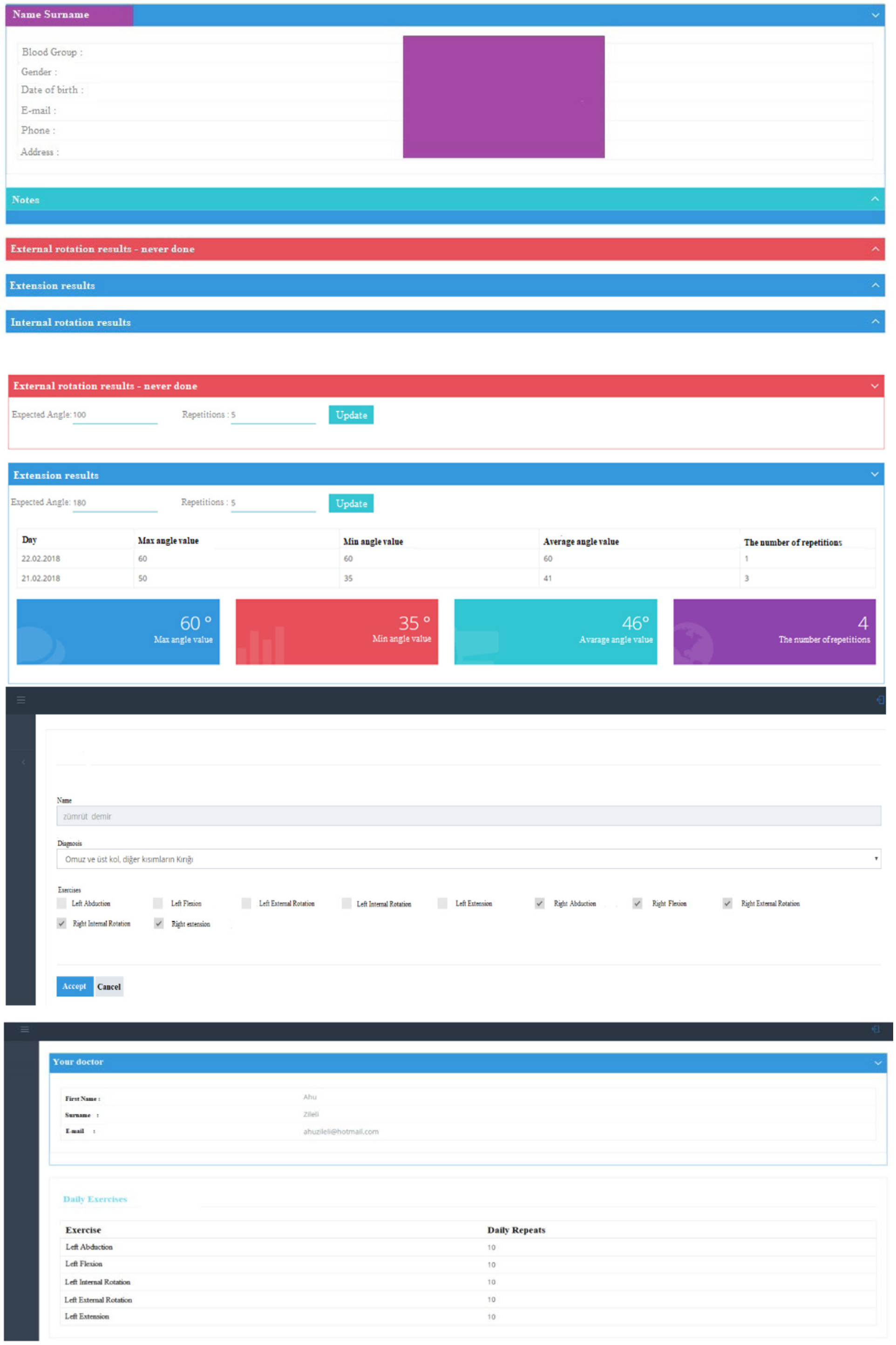

Fig. 8. PhyMen user interfaces.

Table 2
The age, height and body weight values of the participants.

	Test Group		Control Group	
	Man ($\bar{x} \pm$ ss)	Woman ($\bar{x} \pm$ ss)	Man ($\bar{x} \pm$ ss)	Woman ($\bar{x} \pm$ ss)
Age (year)	55.50 ± 17.06	54.00 ± 8.35	52.83 ± 15.82	48.50 ± 8.05
Height (cm)	175.50 ± 9.00	157.91 ± 6.19	171.17 ± 11.05	157.50 ± 4.21
Weight (kg)	88.25 ± 16.09	71.27 ± 9.26	79.17 ± 10.85	72.62 ± 13.78

$\bar{x}$: arithmetic mean, ss: standard deviation.

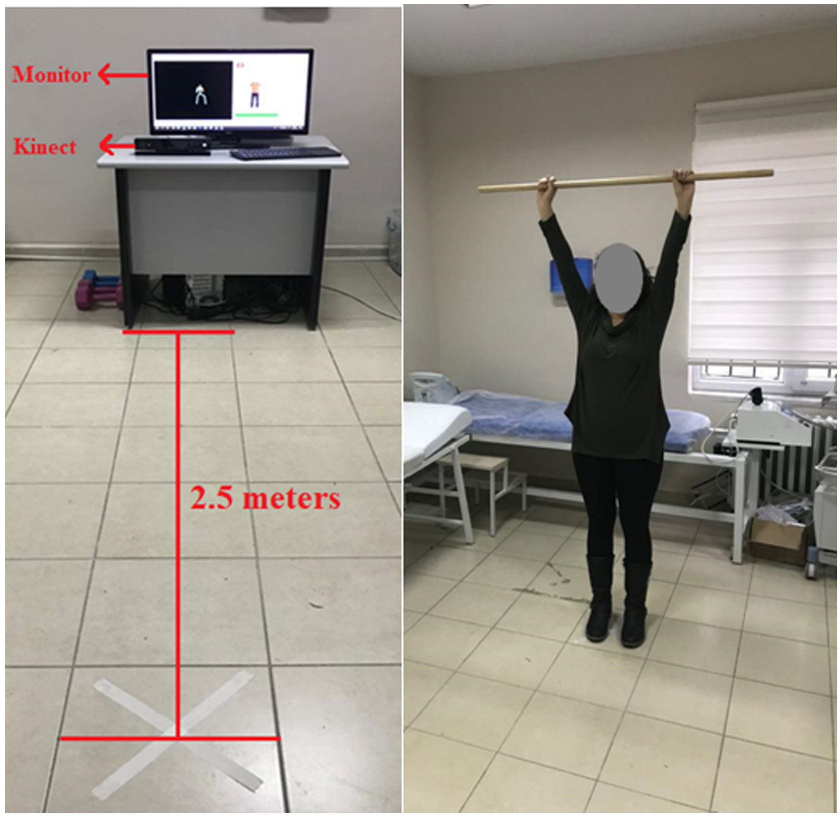

Fig. 9. A volunteer is being treated with PhyMen.

Table 3
The angle measurements of the participants before treatment.

	Flexion		Abduction		Internal Rotation		External Rotation		Extension	
	Control Group	Test Group	Control Group	Test Group	Control Group	Test Group	Control Group	Test Group	Control Group	Test Group
	135	130	125	125	80	75	40	75	25	40
	110	130	100	100	75	70	80	65	35	40
	135	165	110	155	80	70	50	90	35	40
	155	170	125	170	60	85	80	90	35	45
	130	135	110	150	80	80	50	80	30	45
	160	115	150	115	85	80	80	75	45	30
	160	105	155	115	60	80	46	85	35	30
Angle(°)	130	130	110	130	40	65	40	75	30	45
	150	125	135	115	70	70	60	50	35	40
	165	165	160	160	70	75	80	80	40	45
	150	150	120	165	60	70	55	80	45	45
	125	110	120	95	50	70	60	70	45	30
	150	135	155	145	70	80	80	85	40	45
	130	160	70	135	70	75	15	80	40	45
		155		130		75		70		45
Mean	**141.79**	**138.67**	**124.64**	**133.67**	**67.86**	**74.67**	**58.29**	**76.67**	**36.79**	**40.67**

3.2. Procedures

Before and the end of the treatment, the maximum angle values of all participants for all exercises were measured by clinical goniometer (Yıldızlar, Turkey) which is used as a standard 12inch, 360° goniometer with two adjustable overlapping arms. Standard measurement positioning was used by placing the stationary arm parallel to the midline of the thorax, and by moving arm aligned with the shaft of the humerus and lateral epicondyle [32].

Participants were divided into two groups as a control and test group. The participants in the control group performed the exercises with conventional methods. The participants in the test group performed the exercises with PhyMen. The participants in the test group were located about 2 meters away from the Kinect sensor as shown in Fig. 9. All volunteers attended in 12 sessions of physical therapy for 5 days a week in this study.

3.3. Statistical analyzes

In this study, statistical analyzes were obtained using SPSS version 18.0. Descriptive statistics of all variables were calculated as mean and standard deviation ($\bar{x} \pm ss$). Parametric assumptions of the data were evaluated by Shapiro Wilk test and variance homogeneities were evaluated by Levene homogeneity test. The results show that the two groups are homogeneously distributed. Since the data showed nonparametric characteristics,

Table 4
Control group pre-test and post-test comparison.

Exercise/variable	Pre-test	Post-test		
	x̄ ± ss	x̄ ± ss	Z	p
Abduction	124.64 ± 25.00	141.93 ± 22.78	−3.31	0.001*
Flexion	141.78 ± 16.12	155.28 ± 14.90	−3.20	0.001*
External rotation	58.28 ± 20.00	66.07 ± 18.83	−2.73	0.006*
Internal rotation	67.86 ± 12.67	75.36 ± 10.28	−2.75	0.006*
Extension	36.78 ± 6.08	41.07 ± 4.00	−2.81	0.005*

intragroup comparisons were evaluated with Wilcoxon test and intergroup comparisons were evaluated with Mann–Whitney U test. In comparison, $p < 0.05$ shows the statistical significance limit.

4. Results and discussion

Angle measurements of all volunteers in the test group were recorded with PhyMen. Angle measurements of all volunteers were performed with a clinical goniometer before starting treatment for all exercises. The results of these first measurements with clinical goniometer are shown in Table 3. At the end of the treatment, angle measurements were repeated for all exercises with the same goniometer. Fig. 10 shows the angle values before and after treatment for all shoulder exercises.

The blue color indicates the first measurements angles taken before treatment and the red color indicates the last measurements at the end of the treatment. The left side of Fig. 10 is the control group results and the right side is shows the test group results. As can be seen from these figures, the volunteers in the test group have less limitation than the control group.

4.1. Intragroup pre-test post-test comparisons

Wilcoxon test was used to observe the development of the groups within themselves. Table 4 examined the development of volunteers in the control group and Table 5 examined the development of volunteers in the test group.

The pre-test abduction exercise average of the control group is 124.64 ± 25.00, and the post-test mean is 141.93 ± 22.78, and a statistically significant difference is found between two distributions ($z = -3.31$, $p < 0.05$). Flexion exercise average of the control group is 141.78 ± 16.12 for pre-test, and the post-test mean is 155.28 ± 14.90, and a statistically significant difference is found between two distributions ($z = -3.20$, $p < 0.05$). External rotation exercise average of the control group for pre-test is 58.28 ± 20.00, and the post-test mean value is calculated as 66.07 ± 18.83, and a statistically significant difference is detected between two distributions ($z = -2.73$, $p < 0.05$). For internal rotation exercise, pre-test average of the control group is 67.86 ± 12.67, and the post-test mean is found as 75.36 ± 10.28, and a statistically significant difference is seen between two distributions ($z = -2.75$, $p < 0.05$). Pre-test extension exercise average of the control group is 36.78 ± 6.08, and the post-test mean value is 41.07 ± 4.00, and a statistically significant difference is found between two distributions ($z = -2.81$, $p < 0.05$).

The pre-test abduction exercise average of the test group is 133.67 ± 23.33, and the post-test mean is 174.33 ± 6.51, and a statistically significant difference is found between two distributions ($z = -3.41$, $p < 0.05$). For flexion exercise, the pre-test average of the control group is found as 138.67 ± 20.99, and the post-test mean is 172.80 ± 13.51, and a statistically significant difference is obtained between two distributions ($z = -3.41$, p

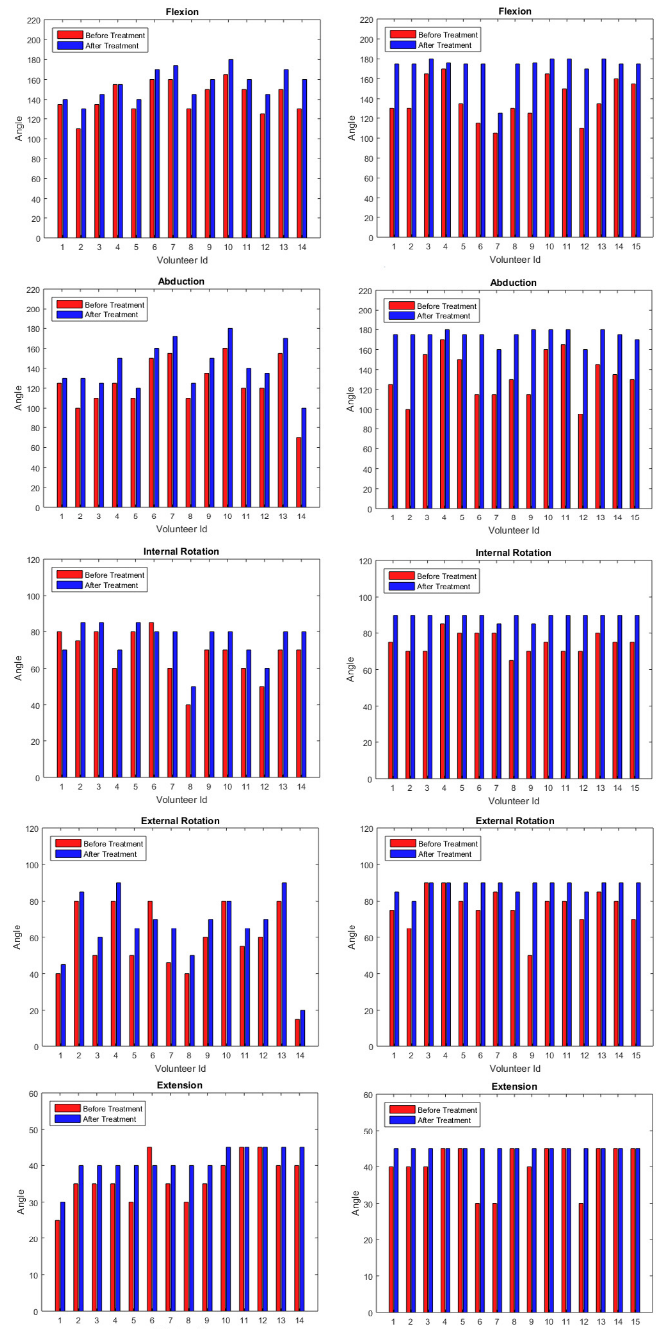

Fig. 10. The angle values before and after treatment for all shoulder exercises.

Table 5
Test group pre-test and post-test comparison.

Exercise/variable	Pre-test	Post-test		
	x̄ ± ss	x̄ ± ss	Z	p
Abduction	133.67 ± 23.33	174.33 ± 6.51	−3.41	0.001*
Flexion	138.67 ± 20.99	172.80 ± 13.51	−3.41	0.001*
External rotation	76.67 ± 10.29	88.33 ± 3.09	−3.22	0.001*
Internal rotation	74.67 ± 5.50	89.33 ± 1.76	−3.43	0.001*
Extension	40.67 ± 5.94	45.00 ± 0.00	−2.43	0.015*

Table 6
Intergroup pre-test results of Mann–Whitney U test.

Exercise/variable		$\bar{x} \pm$ ss	u	p
Abduction	Test Group Control Group	133.67 ± 23.33 124.64 ± 25.00	83.00	0.336
Flexion	Test Group Control Group	138.67 ± 20.99 141.78 ± 16.12	97.50	0.741
External rotation	Test Group Control Group	76.67 ± 10.29 58.28 ± 20.20	72.50	0.146
Internal rotation	Test Group Control Group	74.67 ± 5.50 67.86 ± 16.12	49.00	0.13
Extension	Test Group Control Group	40.67 ± 5.94 36.78 ± 6.08	66.00	0.76

$\bar{x}$: arithmetic mean, ss: standard deviation.

Table 7
Intergroup post-test results of Mann–Whitney U test.

Exercise/variable		$\bar{x} \pm$ ss	u	p
Abduction	Test Group Control Group	174.33 ± 6.51 141.93 ± 22.78	28.00	0.001*
Flexion	Test Group Control Group	172.80 ± 13.51 155.28 ± 14.90	19.00	0.000*
External rotation	Test Group Control Group	88.33 ± 3.09 66.07 ± 18.83	3.00	0.000*
Internal rotation	Test Group Control Group	89.33 ± 1.76 75.36 ± 10.28	22.00	0.000*
Extension	Test Group Control Group	45.00 ± 0.00 41.07 ± 4.00	37.50	0.000*

< 0.05). External rotation exercise average of the control group for pre-test is found as 76.67 ± 10.29, and the post-test mean is 88.33 ± 3.09, and a statistically significant difference is calculated between two distributions ($z = -3.22$, $p < 0.05$). Internal rotation exercise average of the control group is 74.67 ± 5.50, and the post-test mean is obtained as 89.33 ± 1.76, and a statistically significant difference is found between two distributions ($z = -3.43$, $p < 0.05$). For extension exercise, the pre-test average of the control group is obtained as 40.67 ± 5.94, and the post-test mean is 45.00 ± 0.00, and a statistically significant difference is seen between two distributions ($z = -2.43$, $p < 0.05$).

As can be seen from all results of intragroup pre-test & post-test comparisons, the treatment of volunteers in two groups also showed statistically significant positive changes.

4.2. Intergroup pre-test post-test comparisons

Pre-test and post-test comparisons between the groups were made using the Mann–Whitney U test. Table 6 shows the results between the pre-tests and Table 7 shows the results between the post-tests. The first arithmetic mean and standard deviation indicates the statistical results for the test group and the second shows the results of the control group.

The pre-test abduction exercise average result of the test group is 133.67 ± 23.33, and the control group mean result is 124.64 ± 25.00, and no statistically significant difference is found between two distributions ($u = 83.00$, $p < 0.05$). For flexion exercise, the test group mean is 138.67 ± 20.99, and average of the control group is 141.78 ± 16.12, and no statistically significant difference is obtained between two distributions ($u = 97.50$, $p < 0.05$). For external rotation, exercise average result of the test group is 76.67 ± 10.29, and the control group mean result is 58.28 ± 20.20, and no statistically significant difference is found between two distributions ($u = 72.50$, $p < 0.05$). For internal rotation exercise, average result of the test group is 74.67 ± 5.50, and the control group mean result is 67.86 ± 16.12, and no statistically significant difference is found between two distributions ($u = 49.00$, $p < 0.05$). For extension exercise, the test group mean result is 40.67 ± 5.94, and average result of the control group is 36.78 ± 6.08, and no statistically significant difference is found between two distributions ($u = 66.00$, $p < 0.05$).

As can be seen from Table 7, the post-test abduction exercise test group mean result is 174.33 ± 6.51, and average result of the control group is 141.93 ± 22.78, and statistically significant difference is found between the two distributions ($u = 28.00$, $p < 0.05$). For flexion exercise, average result of the test group is 172.80 ± 13.51, and the control group mean result is 155.28 ± 14.90, and significant difference is obtained statistically between the two distributions ($u = 19.00$, $p < 0.05$). For external rotation exercise, the test group mean result is 88.33 ± 3.09, and average result of the control group is 66.07 ± 18.83, and statistically significant difference is found between the two distributions ($u = 3.00$, $p < 0.05$). For internal rotation exercise, the test group mean result is 89.33 ± 1.76, and average result of the control group is 75.36 ± 10.28, and statistically significant difference is found between the two distributions ($u = 22.00$, $p < 0.05$). For extension exercise, average result of the test group is 45.00 ± 0.00, and the control group mean result is 41.07 ± 4.00, and statistically significant difference is found between the two distributions ($u = 37.50$, $p < 0.05$).

Table 8
Recovery rates of test & control groups.

	Test group	Control group
Abduction	% 30.42	% 13.87
Flexion	% 24.61	% 9.52
External rotation	% 15.21	% 13.37
Internal rotation	% 19.63	% 11.05
Extension	% 10.65	% 11.66

As expected from the Levene homogeneity test results, there was no statistically significant difference between the pre-test results for all exercises. In the post-test results, a statistically significant difference was obtained for all shoulder exercises. This shows that there is a difference between the success rates of the two treatment methods. In order to see the level of these differences, the percentages of the two treatment methods were examined in the next sub-section.

4.3. The recovery rates of treatment methods

Within both groups, the percent recovery rate within the groups itself was calculated by Eq. (5). In Eq. (5), x_i signifies the average of the pre-test measurements x_s is the average of the post-test measurements and x_b is the percentage recovery rate. Table 8 summarizes the results of the recovery rates of test & control groups for all shoulder exercises.

$$x_b = 100\frac{(x_s - x_i)}{x_i} \tag{5}$$

As shown in Table 8, volunteers in the test group in abduction, flexion, external rotation, and internal rotation exercises were reduced their limitations at a higher rate than the volunteers in the control group. In extension exercise, the limitation of the volunteers in the control group was decreased by about 1% more than the volunteers in the test group. The reason for the higher performance of volunteers in the control group for extension exercise is that all volunteers in the test group reach an angle of 45°, which is considered the highest value for extension exercise.

5. Conclusion

In this study, Kinect based shoulder physiotherapy mentor system and the statistical results of this proposed system on patients in the hospital are presented. The proposed system consists of a web interface, user interface, and Kinect 2 sensor. The test group consisting of 15 people was treated with Kinect based system and the group consisting of 14 people was treated with conventional methods and comparisons were made between and within the groups. Test results show improvement in patients in both groups.

While the limitations of patients using the proposed Kinect-based treatment system decreased by 30.42%, the limitations of patients who were treated with the traditional method decreased only 13.87%. Likewise, the limitations of the patients using the proposed system in flexion exercise decreased by 24.61%, the limitations in external rotation exercise decreased by 15.21%, the limitations in internal rotation exercise decreased by 19.63%, while the limitations in flexion exercise of the patients treated with the traditional method were only decreased by 9.52%, the limitations in the external rotation exercise were only decreased by 13.37%, the limitations in the internal rotation exercise were decreased by 11.05%. However, the volunteers in the control group show more improvement in the extension exercise. Since all volunteers in the test group reached 45 degrees, the percentage of development of the test group was lower in extension exercise, considering to be the highest performance in the extension exercise. The results show that the developed system is more successful than traditional treatment methods. In addition, the developed system helps to facilitate physiotherapists in monitoring the patient and updating exercises. In this study, in hospital tests, it was observed that patients using the proposed system were more willing to exercise than traditional methods.

The results are promising for the development of home-based rehabilitation systems using Kinect, a low-cost motion capture sensor. In rehabilitation centers, this developed system can be used as an alternative method. In future works, the proposed system can be improved by artificial intelligence methods to predicate the improvement rate of the patients.

CRediT authorship contribution statement

Burakhan Çubukçu: Methodology, Conceptualization, Software, Writing - original draft. **Uğur Yüzgeç:** Supervision, Writing - review & editing. **Ahu Zileli:** Resources, Validation. **Raif Zileli:** Formal analysis, Validation.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Burakhan Çubukçu was born in Ankara, Turkey, in 1988. He received the B.S. degree from the Mathematics Department, Hacettepe University, Ankara, Turkey, in 2012, and Department of Business administration, Anadolu University, Eskişehir, Turkey in 2010. The M.S. degrees from the Information Systems Department, Gazi University, Ankara, Turkey, in 2013. In 2020, he received Ph.D. degree from Department of Electronics and Computer Engineering, Bilecik Seyh Edebali University, Bilecik, Turkey. Since 2021, he has been an Assistant Professor with the Computer Engineering Department, Faculty of Engineering, Bilecik Seyh Edebali University, Turkey. His research interest includes telerehabilitation, computer applications, and intelligent systems.

Uğur Yüzgeç was born in Adilcevaz, Bitlis, Turkey, in May 1974. He received the B.S. degree from the Electronics and Communication Engineering Department, Yıldız Technical University, Istanbul, Turkey, in 1995, and the M.S. and Ph.D. degrees from the Electronics and Communication Engineering Department, Kocaeli University, Kocaeli, Turkey, in 1999 and 2005, respectively. From 1998 to 2010, he was a Research Assistant with Electronics and Communication Engineering Department, Kocaeli University. Since 2020, He has been a Professor with the Computer Engineering Department, Faculty of Engineering, Bilecik Seyh Edebali University, Turkey. His research interest includes intelligent systems and control, fuzzy, neuro-fuzzy systems, meta-heuristic algorithms, unmanned aerial vehicle and numeric techniques in optimization problem.

Ahu Zileli was born in Zonguldak, Turkey, in 1984. She received the B.S. and M.S. degrees from the Physical Therapy and Rehabilitation Department, Abant İzzet Baysal University, Bolu, Turkey, in 2005 and 2019 respectively. Until 2007, she worked some special education and rehabilitation centers in Turkey. Since 2008, she has been physical therapist with the Physical Therapy and Rehabilitation Department, Bilecik State Hospital, Turkey. Her research interest includes surface electromyography, orthopedic rehabilitation and balance.

Raif Zileli was born in Ankara, Turkey, in 1982. He received the B.S., M.S., and Ph.D. degrees from the Physical Education and Sport Department, Abant İzzet Baysal University, Bolu, Turkey, in 2005, 2007 and 2011 respectively. Since 2019, He has been an Associate Professor with the Child Development Department, Faculty of Health Sciences, Bilecik Seyh Edebali University, Turkey. His research interest includes sportive performance, obesity, and anthropometry.