Abstract. [Purpose] The introduction of emerging technologies such as the wireless Blobo bluetooth ball with multimedia features can enhance wrist physical therapy training, making it more fun and enhancing its effects. [Methods] Wrist injuries caused by fatigue at work, improper exercise, and other conditions are very common. Therefore, the reconstruction of wrist joint function is an important issue. The efficacy of a newly developed integrated wrist joint rehabilitation game using a Blobo bluetooth ball with C# software installed was tested in wrist rehabilitation (Flexion, Extension, Ulnar Deviation, Radial Deviation). [Results] Eight subjects with normal wrist function participated in a test of the system’s stability and repeatability. After performing the Blobo bluetooth ball wrist physical therapy training, eight patients with wrist dysfunction experienced approximately 10° improvements in range of motion (ROM) of flexion extension, and ulnar deviation and about 6° ROM improvement in radial deviation. The subjects showed progress in important indicators of wrist function. [Conclusion] This study used the Blobo bluetooth ball in wrist physical therapy training and the preliminary results were encouraging. In the future, more diverse wrist or limb rehabilitation games should be developed to meet the needs of physical therapy training.

Key words: Blobo bluetooth ball, Wrist joint, Rehabilitation

INTRODUCTION

Smooth wrist motion has a significant effect on one’s daily life. Wrist injuries caused by fatigue at work or improper exercise are very common. For example, carpal tunnel syndrome, cubital tunnel syndrome, stenosing tenosynovitis, stenosing tenosynovitis of the flexor tendons, locked finger, thecal cyst, and other symptoms cause great trouble for patients, because in In addition to receiving medical treatment, they have to undergo regular physical therapy1–6). Common exercises include wrist stretches, grip strengthening, wrist extension, wrist radial deviation, wrist flexion, etc. These exercises mainly enhance or recover the patients’ range of motion of the wrist, including wrist radial and ulnar deviation, flexion, and extension movements, as presented in Fig. 1. Although these simple wrist exercises are helpful for enhancing hand strength and preventing future injuries, traditional rehabilitation exercises are quite boring, so patients find it difficult to regularly perform the exercises, thus delaying full recovery. Rehabilitation through physical therapy needs to be progressive and sustainable, and the early success of physical therapy training often influences further training and recovery.
Chang et al. stated that recovery of hand function is the most desired outcome for stroke patients, and that wearing a dynamic hand splint for home-use as a supplementary training program in addition to hospital-based rehabilitation can effectively increase the muscle strength of hemiplegic hands. Kim et al. reported that passive range of motion exercise in the early stage can improve the function of the upper extremities and activities of daily living of patients with acute stroke. Chang et al. investigated the Jebsen-Taylor hand function test, and found that task performance with the cock-up splint was slower than without the splint for all items.

In the current age of advancing information advancements and wireless technology, many medical facilities have begun combining physical therapy with technology. Schering et al. described a training method that combines a Blobo bluetooth ball with music in cooperation with hand gestures to control the game’s character’s motions in order to enhance subjects’ motivation to participate in the activity. Other kinds of music can be added to make the game even more appealing. Lin noted that patients who have suffered strokes are motivated to participate in rehabilitation that involves an audio-visual game controlled by a Blobo bluetooth ball. A game with visual stimulation helps patients to better understand their rehabilitation conditions. Chen et al. reported that patients’ intention to participate in physical therapy increased when the traditional words, digits, and diagrams of the rehabilitation system were replaced by a game with a space shuttle passing through obstacles, a 3D animation game integrated with a human-computer interactive interface of the wrist joint motion rehabilitation system.

This study tested a newly developed lively game using a Blobo bluetooth ball that can train and evaluate the progress of wrist rehabilitation with the aim of evaluating its efficacy in the recovery of wrist functions.

SUBJECTS AND METHODS

Figure 2 shows the general design of the study. The hardware includes an RFID Reader (including Tag), Blobo bluetooth ball, Bluetooth device, etc. The software includes Microsoft Visual Studio C#, Microsoft SQL Server, Adobe Flash CS4, etc. Visual Studio C# is the major program executive, while SQL Server is used to manage the RFID and store the data of the motion of the Blobo bluetooth ball. Flash files are plugged in under Visual Studio C#.

The Blobo bluetooth ball was developed and manufactured by Ball-It, Finland. Multiple sensors are installed in the sphere of the Blobo: a G-Sensor (a triaxial accelerometer detecting g force and sphere movement), a pressure sensor (detecting whether the sphere is squeezed), an electronic gyroscope (calculating the inclination of the sphere), etc.

For physical therapy, traditional movements such as wrist flexion, wrist extension, wrist radial deviation, and wrist ulnar deviation, are performed by manipulating the Blobo bluetooth ball. Figure 3 (a) demonstrates the movements of wrist flexion.
and wrist extension while holding a Blobo bluetooth ball; Figure 3 (b) shows the movements of wrist radial deviation and ulnar deviation while holding a Blobo bluetooth ball. Grip strengthening can also be done by squeezing the Blobo bluetooth ball.

To launch the system, the user has to throw the Blobo bluetooth ball up into the air. Once the Blobo bluetooth ball is wirelessly linked to a computer through Bluetooth, it is ready to be used. The ball is held and moved back and forth horizontally, squeezed, and turned (clockwise, counterclockwise); the actions are detected by the built-in electronic gyroscope, pressure sensor and G-Sensor, and are used to synthesize the motions (swinging horizontally, confirming, and whirling) used within the computer game. The data retrieved from the game is stored in a SQL Server database for subsequent analysis of the training effect.

The Blobo bluetooth ball is linked to a computer through the Bluetooth protocol. The Blobo bluetooth ball is first activated by throwing it up or shaking it, which initiates the computer link the Blobo bluetooth ball. The database for storing the data needs to be created before authentication work can proceed.

Identities are determined through the RFID’s electronic tag (exclusive card number). The administrator can add, delete, and amend data according to the electronic tags and identity management in the database.

After authentication and selection of the level of difficulty (easy, medium, or difficult) and the hand to be trained (right or left), the user can play the manual music player game. When the Blobo bluetooth ball is rotated or swung, it activates the music playing function in C#. If the user stops the motions, it arrests the music function in C#. Depending on the patient’s symptoms, the way the patient holds the Blobo bluetooth ball will vary for flexion, extension, ulnar deviation, and radial deviation.

The subjects swung the Blobo bluetooth ball horizontally and rotated it clockwise (counterclockwise) to play the music while squeezing and patting it to turn the volume up or down. When subjects stop the motion, the music also stops. The system records and analyzes the length of time taken and the occurrence of pauses for clinical reference.

The experiment consisted of two trials separately involving subjects with normal wrist function, and subjects with impaired wrist function. Eight subjects with normal wrist function were invited to participate in 10 training sessions and tests for this study to determine whether the same evaluation effect is generated in terms of the dominant hand to validate the stability and repeatability of the system14, 15.

Eight subjects with impaired wrist function also participate in training and tests twice a week for eight weeks (three rounds/time). They signed the Taipei Medical University Hospital institutional review board-approved informed consent form prior to participating in this study. Each subject was initially interviewed to obtain participant’s background information, and exercise habits.

The assessments of the design of the game and analysis of the subject’s behavior were based on the original length of the music (sec), the length of time taken to play the music (sec), and the occurrence of pauses (occurrence).

With the cooperation of the joints, muscles, and bones, hands are able to complete a variety of complicated motions. Wrists make the following motions: flexion, extension, ulnar deviation, and radial deviation. This study used the range of motion (ROM) of these four motions as indicators. Prior to the test, the subjects practiced once and then performed the test twice. The best performance was recorded. The outcome measures were examined before the start of the study, at the end of the fourth week, and at the end of the eighth week.

**RESULTS**

The hand rehabilitation training device developed for testing in the study was verified using subjects with normal wrist function and subjects with impaired wrist function.

Table 1 shows the 10 training sessions and tests performed by the eight subjects with normal wrist function (R1–R4 had dominant right hands while L1–L4 had dominant left hands). Table 1 shows the averages of the 10 training sessions for either hand performed by the subjects with normal wrist function at the easy, medium, and difficult levels of difficulty (the original lengths of the music were 247 sec, 245 sec, and 237 sec, respectively). Based on the length of time taken to play the music and the number of pauses, the subjects all performed better with their dominant hand (p<0.05).

Table 2 shows the basic information of the eight subjects with impaired wrist function (P1–P8). The entire course of physical therapy lasted eight weeks. The subjects participated in training sessions and tests twice a week (three sets/session). The

**Table 1. The basic characteristics of the subjects with normal wrist function**

<table>
<thead>
<tr>
<th>Participants</th>
<th>R1</th>
<th>R2</th>
<th>R3</th>
<th>R4</th>
<th>L1</th>
<th>L2</th>
<th>L3</th>
<th>L4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gender (M/F)</td>
<td>M</td>
<td>F</td>
<td>M</td>
<td>F</td>
<td>M</td>
<td>M</td>
<td>F</td>
<td>M</td>
</tr>
<tr>
<td>Age</td>
<td>42</td>
<td>35</td>
<td>28</td>
<td>53</td>
<td>56</td>
<td>48</td>
<td>35</td>
<td>28</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>170</td>
<td>159</td>
<td>180</td>
<td>162</td>
<td>168</td>
<td>183</td>
<td>155</td>
<td>175</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>80</td>
<td>58</td>
<td>84</td>
<td>50</td>
<td>72</td>
<td>85</td>
<td>48</td>
<td>73</td>
</tr>
<tr>
<td>Dominant side</td>
<td>Right</td>
<td>Left</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Subjects were asked to train repeatedly by holding the Blobo bluetooth ball and making flexion, extension, ulnar deviation, and radial deviation movements.

P1–P8 advanced to the next level of difficulty in the eight-week training when the average length of time taken to play the music and the average number of pauses/fell below threshold values determined the performance of the subjects with normal wrist function: an average time within 120% of the original length of the music, and an average number of pauses in Easy (Medium) of less than 100 (120) times. Table 3 indicates the performance of the subjects with impaired wrist function during the training.

As presented in Table 3, all of the eight subjects advanced to the next level of difficult during the eight-week training. P1, P2, and P7 advanced to the Difficulty level in week 8 because their dominant hand was the affected hand. P3, P4, and P6 achieved the Medium level in week 8. Although their dominant hand was the affected hand, because their diagnosis was stenosing tenosynovitis, their ability to hold the Blobo bluetooth ball was worse than that of the subjects with carpal tunnel syndrome. P5 and P6’s affected hand was not their dominant hand. Therefore, they could not manipulate the Blobo bluetooth ball easily and only achieved the Medium level of difficulty in week 8.

The performance evaluation was measured at the limit when subjects did not feel pain in flexion, extension, ulnar deviation, and radial deviation. Table 4 shows that the ROM of the eight subjects with impaired wrist function improved by 8–13° in flexion; by 7–10° in extension; by 1–3° in ulnar deviation; and by 4–5° in radial deviation. Therefore, the subjects showed marked improvement in each of these measures.
Table 4. Outcome measures testing results of the patients

<table>
<thead>
<tr>
<th>Indicators &amp; Subjects</th>
<th>Flexion (deg)</th>
<th>Extension (deg)</th>
<th>Ulnar deviation (deg)</th>
<th>Radial deviation (deg)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pre</td>
<td>Middle</td>
<td>Post</td>
<td>Pre</td>
</tr>
<tr>
<td>P1 (R,R)</td>
<td>40</td>
<td>46</td>
<td>53</td>
<td>30</td>
</tr>
<tr>
<td>P2 (R,R)</td>
<td>37</td>
<td>43</td>
<td>49</td>
<td>27</td>
</tr>
<tr>
<td>P3 (R,R)</td>
<td>71</td>
<td>72</td>
<td>72</td>
<td>62</td>
</tr>
<tr>
<td>P4 (R,R)</td>
<td>70</td>
<td>71</td>
<td>71</td>
<td>60</td>
</tr>
<tr>
<td>P5 (R,L)</td>
<td>33</td>
<td>36</td>
<td>41</td>
<td>28</td>
</tr>
<tr>
<td>P6 (L,L)</td>
<td>73</td>
<td>73</td>
<td>73</td>
<td>62</td>
</tr>
<tr>
<td>P7 (L,R)</td>
<td>38</td>
<td>45</td>
<td>51</td>
<td>28</td>
</tr>
<tr>
<td>P8 (L,R)</td>
<td>34</td>
<td>38</td>
<td>44</td>
<td>24</td>
</tr>
</tbody>
</table>

(R, L) means the dominant hand is the right (R) while the affected hand is the left (L), and vice versa.
Pre: at the start of the intervention, Middle: at the end of week 4, Post: at the end of the intervention

DISCUSSION

Traditional wrist rehabilitation is repetitive, monotonous, and boring, and the training progress cannot be automatically stored and analyzed. This study introduced and tested an interactive multimedia training game using a Blobo bluetooth ball with the aim of providing a diversified and lively physical therapy method for wrist rehabilitation. The motivation to participate in training can be enhanced through a fun interactive multimedia device, making traditionally tedious and boring training or health enhancement activities more interesting. The introduction of the RFID technique in this study for identification and authentication allows rapid recording, retrieval, and analysis of data acquired by the rehabilitation game, including training dates, length of time, etc.

The system developed for this study automatically collects the data regarding the participants’ performance, and computes increases in levels of difficulty based on the length of time taken to play music during the training. After the training, all the participants’ wrist ROM were performed better than at the beginning of the physical therapy, proving that wrist rehabilitation with the Blobo bluetooth ball has positive effects and is worthy of further study.

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REFERENCES

12) Chen PW, Wu HY, Wu SS, et al.: The study of virtual reality module applied to advance interest of twist joint rehabilita-