

Sonic Wave Vibration Based Sling Exercise System Using Bluetooth Serial Port Profile (SPP)

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Abstract: Sling exercise therapy has been used for active exercise therapy fields. However, a rehabilitation therapy using the sling exercise has limits from pain and reluctance. To solve the problems of the sling exercise for a therapy, we propose a sling exercise system using sonic wave vibration. The proposed system is composed of two parts, a sling machine using Sonic Wave Vibration (SM-SWV) for adjusting precisely frequency and intensity and a mobile Application (App.) for Managing the Sling Machine (MA-SM). The SM-SWV is implemented for adjusting precisely frequency and intensity according to various physical conditions of users. The MA-SM is used for controlling the proposed sling machine and connected to the sling machine via Bluetooth Serial Port Profile (SPP). In the proposed sling exercise system, the proposed exercise mode classifies various symptoms of the patients who require treatment of muscle skeletal rehabilitation into four categories. Four types of sling exercise modes are as follows, open kinetic chain mode, closed kinetic chain mode, functional instability mode and functional movement mode. The four sling exercise modes are designed to enable various treatments to be applied depending on the symptom of the patients who require the rehabilitation of the skeletal system. Also, the proposed sling machine supports the free management mode for setting directly control items such as exercise modes, execution time and repetition time. It is necessary to manage appropriately the rehabilitation training program according to the patient's state. In the implementation results, the user interface of the MA-SM is designed to select freely patient information, four types of exercise mode and execution time. Based on the control information transmitted from the MA-SM it is observed that the SM-SWV generates waveforms with various frequencies and intensities. It is expected that the proposed sling exercise system could provide appropriate rehabilitation programs according to patient status.

Key words: Sling exercise, sling machine, sonic wave vibration, rehabilitation, mobile application using Bluetooth, SM-SWV generates

INTRODUCTION

Sling exercise therapy is an active exercise therapy for treating an injured area and promoting a health. It utilizes mainly a shaking string to perform an exercise therapy to patients (Kyoung-Kyu and Sang-Yong, 2016; Seung-Jin and Won-Je, 2015; Joon and Tae-yeon, 2014; Jong-Sung *et al.*, 2014; Jinyoung, 2009). In addition, patients who require biomechanical rehabilitation due to aging or disease or those who are in a hospital for long periods after surgery, require more strengthening of micro-muscles rather than internal muscles. Figure 1 shows the treatment appearance of patient using sling exercise.

However when the sling exercise is applied to patients who need a rehabilitation treatment it has a lot of time and limits from the pain and the repulsion from the



Fig. 1: Treatment appearance using sling exercise

exercise. Hence, the rehabilitation therapy using a sling exercise is a big challenge (Jin-Young, 2009; Jae-Koo, 2007).

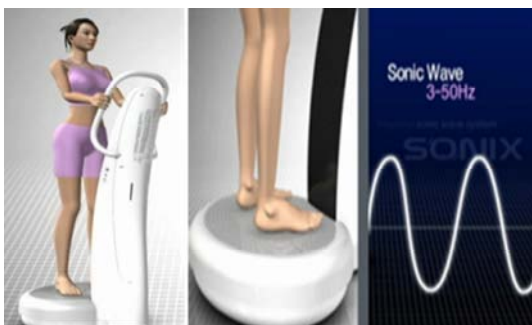


Fig. 2: Body exercise machine using sonic wave vibration

In this study, we design a Sling Machine using Sonic Wave Vibration (SM-SWV) and a mobile Application (App.) for Managing the Sling Machine (MA-SM). As shown in Fig. 2, the whole body exercise machine based on sound wave vibration has been used for increasing muscle strength and helping recovery of muscle cells by applying the sound vibration of a low frequency such as a woofer speaker to the treatment area.

The proposed SM-SWV is designed for adjusting precisely frequency (Hz) and intensity (Walt) according to various physical conditions and symptoms of users. It has been shown to be effective in various treatments for patients requiring muscle rehabilitation by minimizing the pain and exercise reluctance (Jin-Young, 2009). It has the advantage of performing various treatments for patients who require muscle skeletal rehabilitation. Also, it minimizes the pain and exercise rejection that occurs during a rehabilitation muscle training and strengthens the micro-muscles of the whole body (Jin-Young, 2009; Jae-Koo, 2007).

In order to control the SM-SWV, we implement an MA-SM based on Android platform using Bluetooth 2.0 Serial Port Profile (SPP). The mobile Application (App.) supports patient information and four sling exercise modes. If a user sets the patient information, the sling exercise mode and execution time, the exercise command is transmitted to the sling machine using Bluetooth module and sling exercise treatment is performed. Bluetooth is a short-range wireless communication technology using 2.4 GHz band radio frequency and has very low power consumption and high reliability due to high-speed frequency hopping (Bluetooth SIG., 2014; Xu *et al.*, 2011). Since, all devices using Bluetooth communication can communicate with each other, the implemented sling machine using sonic wave vibration can communicate with all portable terminals with Bluetooth (Je and Yang, 2012; Do-Sun and Dong-Gyu, 2012; Duck-Young and Dong-Gyu, 2008; Jung-Kyou and Young-Kil, 2001).

MATERIALS AND METHODS

System overview: Figure 3 shows the overall structure of the proposed sling exercise system based on sonic wave vibration. Our proposed system is composed of two parts: a Sling Machine using Sonic Wave Vibration (SM-SWV) and a mobile Application (App.) for controlling the Sling Machine (MA-SM).

The SWV-SM is implemented for adjusting precisely frequency and intensity according to various physical conditions of users. It is cylindrical as shown in Fig. 3. The sling exercise is performed by connecting lines at the top and bottom. The external and internal view of the sling machine is included also in Fig. 3. The mode selector is used for changing power on/off and exercise mode. LED status indicator represents remaining battery levels in the SWV-SM. The generator of sonic wave vibration is located at the center in the SWV-SM and generates sonic vibrations of various sizes. The SM-SWV uses SPP (Serial Port Profile) (Joon and Tae-yeon, 2014) in a Bluetooth module to receive frequency and intensity values for various exercise modes from the MA-SM.

The MA-SM is used for controlling the proposed sling machine and connected to the sling machine via Bluetooth. If user information, sling exercise mode and execution time are set and the start button for sling exercise is pressed, the exercise command is transmitted to the SM-SWV through Bluetooth and it is applied to a user. Four types of sling exercise modes are supported, open kinetic chain mode, closed kinetic chain mode, functional instability mode and functional movement mode. The four sling exercise modes are designed to enable various treatments to be applied depending on the symptom of the patients who require the rehabilitation of the skeletal system.

Proposed sonic wave vibration based sling exercise system using Bluetooth Serial Port Profile (SPP) Sling Machine using Sonic Wave Vibration (SM-SWV):

The internal structure of the SM-SWV machine including a Bluetooth communication module is shown in Fig. 4. The mode selector controls the change of operating frequency and the start and stop operation of sonic wave vibration. The LED status indicator represents the remaining battery level using three different colors. Blue color indicates that the sling machine is fully charged state and red color represents that the sling machine is now operative. Finally, red color indicates that the battery needs to be charged.

The Bluetooth module is used for data communication with the sonic vibration control Application (App.). The digital sine wave data from the Micro Controller Unit (MCU) is converted to an analog sine signal through a Digital to Analog Converter (DAC).

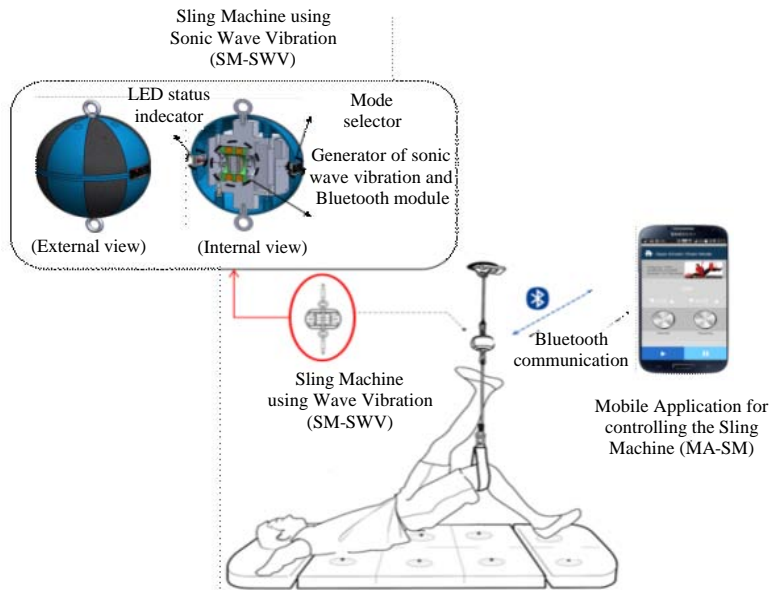


Fig. 3: Overall structure of the proposed sling exercise system

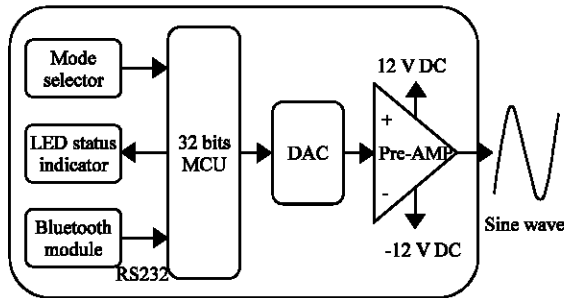


Fig. 4: Internal structure of the SM-SWV machine including mode selection button, LED status button and Bluetooth communication module

Lastly, the Pre-AMP (Amplifier) removes the noise of analog sine signal and manages the amplitude of the signal.

The procedure of the SM-SWV is shown in Fig. 5. First, a port for data communication is initialized and battery level is checked. The battery level is displayed to a user through LED status indicator. If the battery level is sufficient, Bluetooth connection between the sling machine control application and the sling machine is checked. If Bluetooth connection is completed, a sine wave is generated by referring to the frequency and intensity of the transmitted control packet. If Bluetooth connection is not available, we check the battery level and wait the connection.

Mobile Application (App.) for controlling Sling Machine (MA-SM): Figure 6 shows a Bluetooth-based

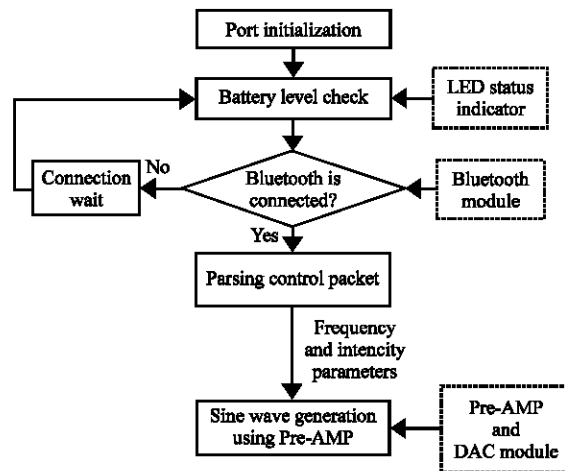


Fig. 5: Procedure of SM-SWV

communication protocol between the Sling Machine using Sonic Wave Vibration (SM-SWV) and the Mobile App. for the sling machine (MA-SM). First, the SM-SWV is searched and the mobile device and the sling machine are connected through the pairing process. According to the patient's condition, exercise mode, frequency intensity, execution time and the number of repetitions are set in the control packet of the MA-SM. When the start button is pressed, the control packet is delivered into the sling machine and the selected exercise mode is performed. When it is completed, the sling machine sends the completion message of the exercise treatment and the connection is terminated.

Structure of control message:

- ID (2 byte)
- Patient name (2 byte)
- Exercise mode (2 byte)
- Frequency (2 byte)
- Intensity (2 byte)
- Execution time (2 byte)
- Number of repetition (2 byte)

The control message structure between two devices. The total message consists of 18 bytes and CRC (Cyclic Redundancy Check) code for error checking is omitted.

Table 1 shows the detailed descriptions and values of each item in the control message. ID is the unique number of the smart device. The exercise mode is configured to select four exercise modes and it can be added in the

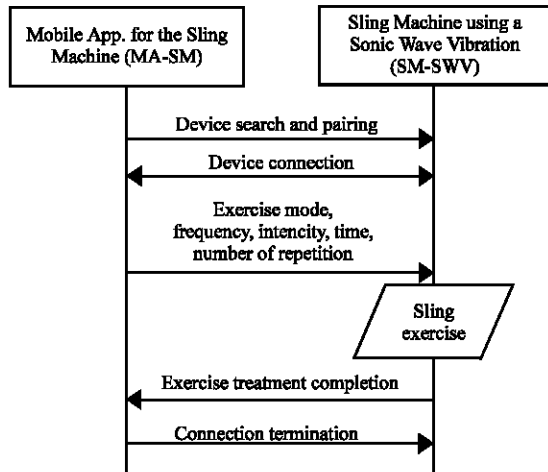


Fig. 6: Bluetooth based communication protocol between SM-SWV and MA-SM

future. The other frequency intensity, execution time and the number of repetitions require different settings depending on each exercise mode.

According to the exercise effects, Fig. 7 shows the proposed four exercise modes. Exercise effects consist of muscle relaxation and stretching effects, strength and endurance enhancement, dynamic muscle stabilization effects, body awareness and balance. Four exercise modes are set according to each exercise effect and it was configured for efficient rehabilitation exercises by controlling frequency and intensity, execution time and repetition frequency of control items of the sling machine.

The proposed exercise mode classifies various symptoms of the patients who require treatment of muscle skeletal rehabilitation into four categories. Also, the sling machine could be configured without setting directly control items. In addition, since, the proposed sling exercise system based on sound wave vibration could control precisely intensity and frequency it is possible to manage appropriately the rehabilitation training program according to the patient's state. As a result, the proposed control app could be configured to perform optimal rehabilitation training.

Table 1: Detailed descriptions and values of each item in the control message

Items	Description or values
ID	Unique number of MA-SM to be connected to SM-SWV
Patient name	Patient name
Exercise mode	Open kinetic chain mode-(0000 0001) Closed kinetic chain mode-(0000 0010) Functional instability mode-(0000 0100) Functional movement mode-(0000 1000)
Frequency	3-150 Hz
Intensity	12 W, DC 12 V
Execution time	Execution time for SM-SWV
Number of repetition	Number of repetition of the selected exercise mode

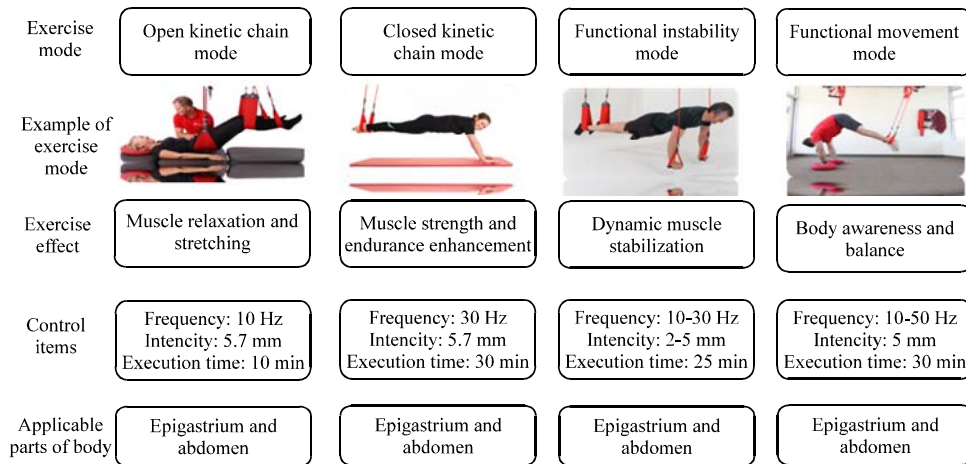


Fig. 7: Proposed four exercise modes according to exercise effects

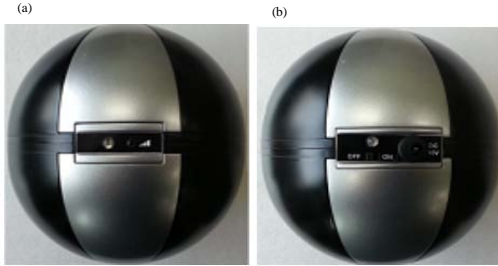


Fig. 8: External view of the implemented SM-SWV; a) Front view and b) Rear view

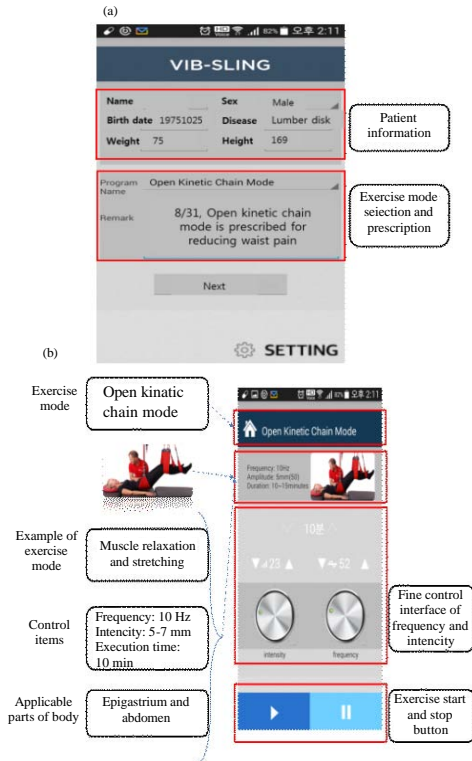


Fig. 9: Screen shots of the implemented MA-SM; a) Screen shot of patient information and sling exercise mode selection and b) Screen shot of frequency and intensity settings according to the selected sling exercise mode

RESULTS AND DISCUSSION

In this study, we show the implementation results of the proposed sling exercise system using sonic wave vibration system. The Sling Machine using Sonic Wave Vibration (SM-SWV) is built as shown in Fig. 8 and the Mobile App. for the Sling Machine (MA-SM) is implemented in Android 4.0 version.

Figure 9 shows the implemented results of the MA-SM. Figure 9a shows a screen to enter patient

information, exercise mode selection and exercise prescription contents before starting sling exercise. These data are stored in a database to help the patient's prescription history and treatment.

The implementation result of the MA-SM is shown in the right side of Fig. 9. The title at the top shows the name of the selected exercise mode among four exercise modes. "Open kinetic chain mode" among four exercise modes is used as an example. In the next column, the description including picture of the exercise mode is appeared. The third column shows frequency and intensity values controlled by a user. A fine-tuning interface is located in next column to adjust the frequency and intensity as needed. In addition to the proposed four exercise modes, a fine-tuning interface is provided to adjust variously frequency (Hz) intensity, execution time and repetition number according to the user's physical conditions and symptom. At the end, we added start and stop buttons to control the start and end of the exercise.

CONCLUSION

In this study, we proposed a sonic wave vibration based sling exercise system using Bluetooth Serial Port Profile (SPP) which is designed to adjust precisely frequency (Hz) and intensity values according to the user's physical conditions and symptoms. The proposed system is composed of a Sling Machine using Sonic Wave Vibration (SM-SWV) and a Mobile Application (App.) for controlling the Sling Machine (MA-SM). The SWV-SM is implemented for adjusting precisely frequency and intensity according to various physical conditions of users. The MA-SM is used for controlling the proposed sling machine and connected to the sling machine via. Bluetooth. It is expected that the proposed sling exercise system could provide an appropriate rehabilitation training program according to the patient's condition by precise intensity and frequency control.

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