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Haptic Body Position Improver during A Workout

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ABSTRACT

Fitness is one of the popular physical activities performed individually most of the time. While doing an activity, if the proper posture is not adopted, it can result in major injury that makes it difficult to lead a healthy life. By adopting wearable technology and haptic technology not only correct motion could be achieved but also damages due to wrong motion could be prevented. In this article we introduce a simple and convenient wearable device that can sense the position of the body during the exercise and provide haptic feedback if an improper motion was performed. The wearable system includes four gyroscopes and four coin types of vibration motors. The body position was recorded using gyroscopes and haptic feedback was applied using vibration motors. To test the system three positions were chosen and tested on five participants. The results show that the device can be used by people to have an injury-free activity where a coach is not available.Using wearable technology accompanied by the haptic feedback will improve the skills and will lead to an injury free exercise.

Keywords: Haptic, Sport, Wearable devices

1. INTRODUCTION

There is no doubt that regular physical activity and exercise improve both physical and mental health. Exercise has several well-known health advantages, including helping people manage their weight, preventing diseases, enhancing mental stability, and promoting better sleep. However, doing the wrong move can cause serious injury. The fast-paced world has come to a complete stop due to the COVID-19 pandemic in recent years. The pandemic's effects are severe, and social segregation is the only method for slowing the disease's rapid spread. The imposed lockdown has hampered many aspects of people's lives, including routine fitness activities of fitness freaks, which has led to a variety of psychological issues and serious fitness and health concerns (1). Therefore, people have to perform fitness tasks individually that will impose their bodiesat a risk.

Getting hurt in fitness is very common. Muscle pull,

Shoulder damage, Knee dislocation, etc. are examples of these damages. There are some guidelines to avoid injury such as warming up, stretching, cooling down, and adjusting duration, time, and frequency. However, even if a person performs all these items, there is still a chance of getting hurt due to the wrong motion. Especially when there is no coach to control these parameters, the possibility of getting damaged increases. According to the study by Gray et al.(2) which was performed on 2,873 cases, it was identified that injuries due to overexertion were the most common (36.2% of all cases) among all the injuries. To control these damages new technologies such as wearable and haptic technologiescould be adopted.

Wearable technology has gained popularity across the globe, whether in the shape of a device or accessory. As its name suggests, is a technology that a person can wear. This could be a clip-on item, or it could be the clothes themselves. They remain close to the wearer and capture information aboutthe body. Despite the negative repercussions of utilizing these technologies, some of them are becoming more focused on enhancing human health(3). These tools are made to assist users in planning their activities and making better decisions. These devices' interfaces provide users the ability to browse through daily data and monitor their development. Due to their greater accessibility and availability in places where healthcare professionals are not always present, wearable gadgets are finding widespread use in rehabilitation therapy programs.

Besides wearable devices, haptic science grabs much more attention when they are combined with wearable technology for physical therapy. Haptic feedback is computer-controlled feedback that the human body perceives as a sense of touch (4).This feedback and its effect are achieved by a device that transfers different modalities like the vibration from a computer to a user.

In this study,a wearable device combined with haptic technology to prevent injury in the fitness sport was developed. The purpose of this study is to determine if a gadget withvibrotactile feedback can aid users to correct their motion when the bodyis being worked out with weights.

1. BACKGROUND

Fitness is one of themost popular sports in society and its popularity growing over the years. According to the statistics working out with weights ranks first in the USA(5)over the past 12 months. However, lifting strategies may cause injury in the body which mostly occurs in the lower back and shoulders. Results areacute and traumatic which require hospital treatment(6). Due to a lack of supervision, a technological solution must be utilized to prevent these injuries.

Several studies address using technological advancement for rehabilitation, motor learning, and position awareness (7), (8), (9). Kim et al. (10)developed the ErgoTac device to improve human ergonomics in the execution of heavy or repetitive industrial tasks. The developed wearable device was tested on ten subjects. The results showed that the physical overloading could be reduced usingErcoTac. In another application, a gadget was introduced by Visser et al.(11)for posture correction. To correct the posture of the user, haptic feedback is applied at the back. The provided tactile feedback keeps the body positioned up straight. Ghasemzadeh et al. introduced a golf swing training system that incorporates wearable motion sensors to obtain inertial information. A model was developed which was later used to evaluate the effectiveness of the proposed solution (12).

In some applications Electrical Muscle Stimulation (EMS) were used to guide the body to the desired position. Let Your Body Move toolkit was developed by Pfeiffer et al. (13,14)using EMS. Tactile feedback was felt at the position at which the current is applied. The perceived strength depends on the amount of current, pad size, and density of receptors in the skin. The system showed potential in areas like learning movements, recognition, and recall.EMS has also been used to create heavy object feeling in virtual reality in which haptic EMS effects were used to demonstrate the effectiveness of the solution (15). Besides, electrical stimulation was utilized in a study by Wiesener et al.(16)to control people with lower back damage while swimming. Waterproof electrodes and inertial measurement units (IMUs) were used for training and conditioning. In some studies,the Trackstar motion capture system was adopted by the researchers. Although this device provides the possibility to capture the body motion it is expensive and bulky to implement in real life (17), (18).

The other application mostly emphasized on sensing than providing haptic feedback. These applicationswhich rely on different innovations were summarized in(19), (20), (21), (22). One of these applicationswas the assessment of foot kinematics during running to prevent injury in running. Biomechanics and errors in applied training loads are often cited as causes of running-related injuries(23). Foot-mounted inertial sensors were employed to assess foot kinematics in the steady state running(24). Therefore, running-related mechanics were identified. In other studies such as (25) and (26),wearable sensing device was integrated into a different position on the body for gait analysis and intervention (27).

In this paper, we use sensors and actuators to guide users who are lifting heavy weights in the gym. The device is composed of simple, affordable, easy-to-control parts that demonstrate the potential of using this method to prevent injuries in physical therapy.

1. METHODOLOGY

The developed wearable gadget consists of two parts sensing and actuation. Both parts are cost-effective and easy to use. The sensing part is composed of four 6-axis MPU 6050 motion tracking devices. It can measure acceleration in x, y, and z direction and Roll, Pitch, and Yaw angle simultaneously. It has a small 4 mm × 4 mm size without an installation board which works based on the I^2C communication protocol. It includes different full-scale ranges and sensitivity. In this application,±20g and a sampling rate of 500 Hz were selected. For actuation, four coin-type vibration motors were chosen (Fig. 1). Both units were glued to a fabric pad and were wrapped around the hand using a Velcro fabric strip. They were fastened to a position close to the wrist and to the shoulder. The actuators will be activated if sensors detect deviation from desired locations. To control the system two Arduino UNO microcontroller for each hand was used. To select a specific motion program five switches were considered. When a switch was turned on, a dedicated program to that exercise was activated.The whole system was put in a bag for easy carrying and to avoid interfering a motion while doing an exercise.

1. EXERSICES

As stated earlier when performing a physical activity like lifting a heavy object, the body might be injured not only because of the excessweight but also

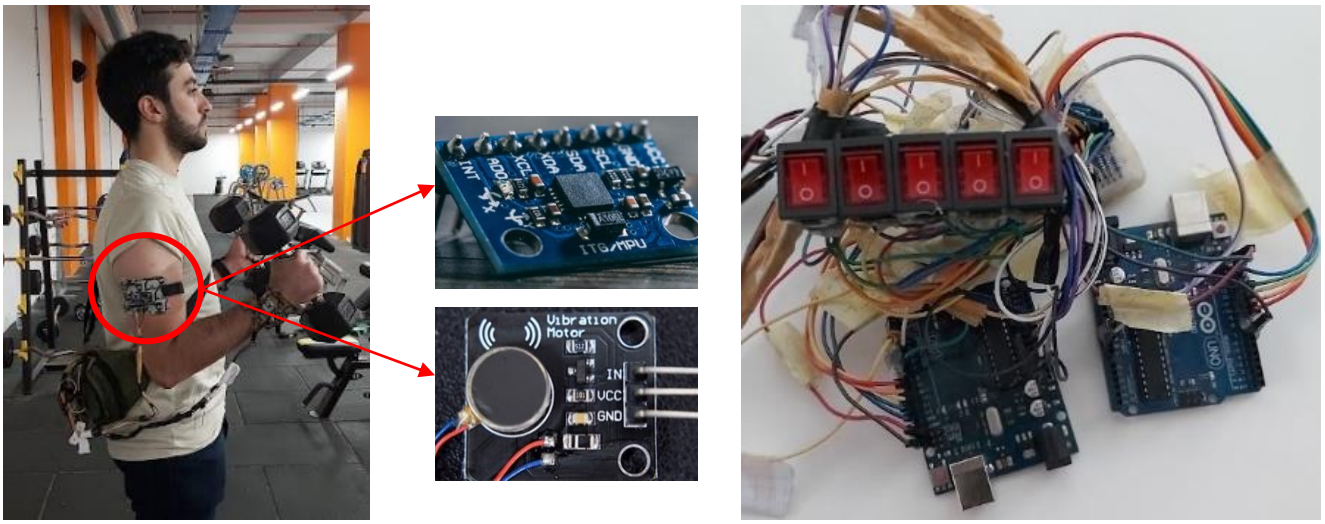


Fig 1: The system is composed of two Arduino boards. Four 6-axis MPU 6050 gyroscopes and four coin-type vibration motors. Five switches were integrated into the system to select the specific exercise. However, three motion was chosen. The whole system was carried in a bag which was fastened around the user.

huge mechanical load is applied to the different parts of the body involved in the motion. In most cases, the hand is used to lift the object. This may result in shoulder pain, shoulder tendon injury, a twist, an unwanted load to the spinal cord, etc. For this reason, five positions related to the upper part of the body were selected for the study. They are Dabbling curl hammer, Biceps with dumbbells, Forearm with dumbbells, Shoulder press dumbbells and lateral shoulder.

4.1 Dabbling curl hammer

The dumbbell hammer curl is an arm builder exercise and is used to develop arm thickness by affecting the arm's muscles. To perform this motion feet stand together about shoulder length apart with a slight bend in the knee. Elbows are kept slightly in front of the hips to make sure that the biceps are engage during

the motion. Dumbbells are raised 90 degrees and back down. because of the wrong motion. When lifting is done

4.2Shoulder press dumbbells

The shoulder press dumbbell is a shoulder exercise that not only trains shoulder muscles but also other muscles such as forearms. To perform this motion the subject is sat on an upright bench. Dumbbells are held above the shoulder where the palm is facing away from the body. The weight is pushed toward the ceiling until the elbows are reached a straight position. The weight should not slam together.

4.3 Lateral shoulder

The Shoulders are made of different muscles such as the anterior, the lateral, and the posterior deltoid. This motion is adopted to put pressure on the shoulder muscles. To perform this motion, the weights are held next to the side of the body about shoulder apart and with a slight bent in the elbows and knees. They are raised straight out to the sides.

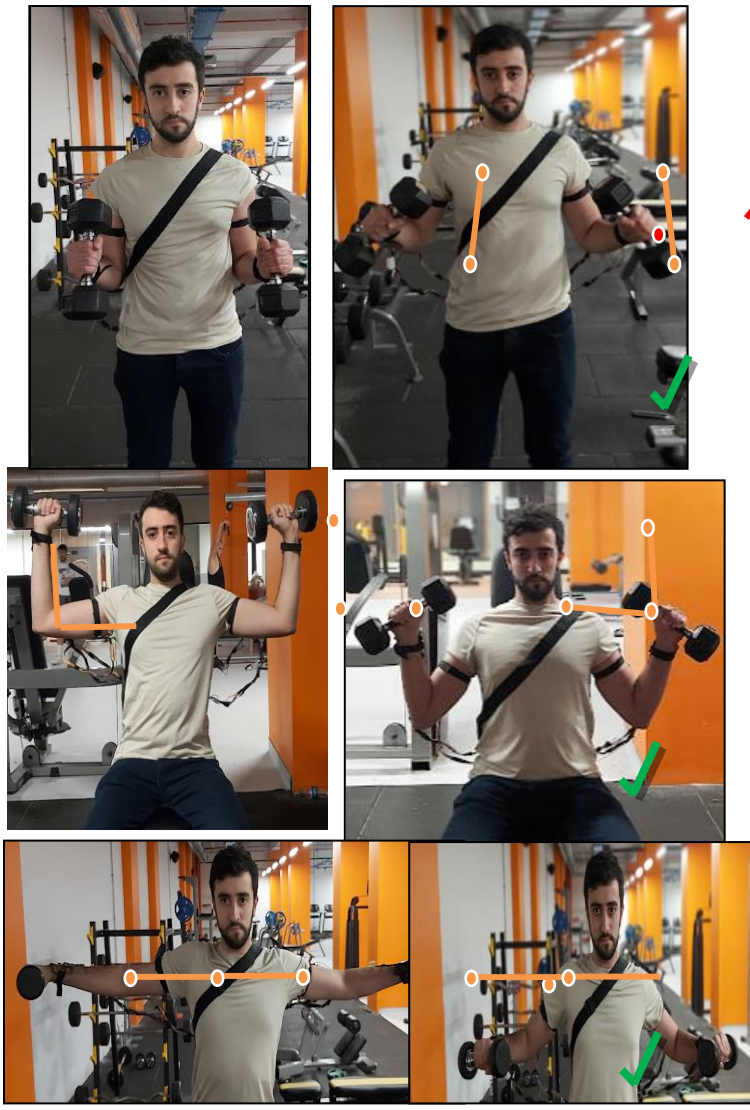
1. EXPERIMENTAL EVALUATION

The data related to each motion were observed in two phases. In the first phase,the proper movement for each subject was recognized and acceleration data related to the motion were recorded. In the second section, participants were asked to perform arbitrary

movements and check if they feel vibration feedback in their arms. All these procedures were performed in one session to have accuracy in recording and not missing sensors' proper locations. Note that only acceleration data were noticed and the orientation part was not considered.

The performance of the system was evaluated on 5 participants. Four males and one female (Mean age 22.4 ±8.1, age range 20-30 years) participated in the study after signing a written informed consent. Three subjects had prior exercise experience in the gym. Each subject was requested to perform each motion in two sets and ten repetitions. In the end, they were required to answer the questions regarding their experience and rate it from one to ten. Where one is the lowest score and ten is the highest. Figure 2 shows the correct and incorrect motions when a subject performs all the exercises using the wearable gadget.

Fig 2: Shows three exercises performed by a subject in correct and incorrect positions. Top) Is a Dabbling curl hammer motion where in the correct position hands are straight with 90 degrees angle. Middle) Is a Shoulder press dumbbell where subjects start from 90 degrees angle in the ankle and raise the weights. Down) Is a Lateral shoulder where the subject tries to hold the weight in a straight position.



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1. RESULT AND DISCUSSION

Table 1 was prepared according to the answers provided by the subjects. It could be inferred from this table that nearly all of the participants found the gadget useful and prefer to use it in the future. And also found the location of the sensor and actuator suitable for the experiment. However, most found the intensity of the vibration inadequate which requires increasing intensity. However, according to questions 1 and 2, they have been able to recognize the position of the vibration motors. Some participants suggested adjusting the vibration according to the occurred error.This means lower error between desired and current location will lead to a lower vibration rate and vice versa. This idea will be considered in the future.

Based on the 5, most of the users indicated that no training was needed. This shows how easy to use and

applicable the proposed system is. Besides cables were stated to be problematic for subjects which this point will be considered in the future development the more compact communication system will be developed.

Table 1: Following questions were asked from participants after performing an exercise

1	To what extent were you able to locate the vibrations generated by vibrations motors?	7
2	To what extent were you able to identify the location of the vibration along the hand?	8
3	How suitable are the vibration intensities for you?	6
4	How well did you feel the accelerometers and vibration motor were properly located	9
5	To what extent did you need a training stage?	4
6	To what extent do you think the gadget?	6
7	How is useful as an add-on for sports?	9
8	How uncomfortable were the cables for you?	5

7. CONCLUSION

In this study, the wearable device capable of providing tactile feedback to a subject while doing an exercise was introduced. The provided haptic feedback was utilized to guide the user to correct the motion and avoid injury during the gym activity. The system is composed of a set of sensors and actuators to record the hand position and apply vibration. The performance of the proposed method was tested by five participants in a real case. The results show that haptic feedback could be used in sports as an essential tool to avoid injury.

8. FUTURE WORK

The first point to consider in the future study is to develop a wireless system that will eliminate the wiring and will provide a better motion range. This could be archived by adding Bluetooth communication ports between the control point and destinations. Another important point is to make the prototype an autonomous system. In this system, there is no need to save the specific position data for each user. Different techniques such as artificial intelligence could be used to recognize hand postures. This will allow the current system to respond in dynamic motion than the static position which limits the application of the current prototype.The next step could be using muscle factors. Recording muscle conditions and combining this information with the current system will avoid athletes to use excessive loads.

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