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ACIBADEM MEHMET ALİ AYDINLAR UNIVERSITY

INSTITUTE OF NATURAL AND APPLIED SCIENCES

DEVELOPMENT OF A WEARABLE BALANCE SENSOR THAT PROVIDES REAL-TIME TACTILE BIOFEEDBACK AND PRELIMINARY TEST RESULTS ON PEDIATRIC BRAIN TUMOR PATIENT

Begüm YALÇIN

DEPARTMENT OF MEDICAL ENGINEERING

SUPERVISOR

Asst. Prof. Hande Argunşah Bayram

SECOND SUPERVISOR

Asst. Prof. Mehmed Buğrahan Bayram

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DECLERATION

I declare that the works and information contained in this thesis are my own except where explicitly stated otherwise in the text. I am fully aware of all the ethical rules and there are not any violation of copyright and any kind of patent.

19/04/2019

Begüm Yalçın

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LIST OF SYMBOLS & ABBREVIATIONS

°/s	Angular Velocity
3D	Three-dimensional
ACL	Anterior Cruciate Ligament
ACU	Acıbadem Mehmet Ali Aydınlar University
BMI	Body Mass Index
BPM	Beats per Minute
CAD	Computer Aided Design
COG	Center of Gravity
COM	Center of Mass
cm	Centimeter
CS	Control Subject
CS WO FB	Control Subject Without Feedback
CS W FB	Control Subject With Feedback
DC	Direct Current

Hz	Hertz
I2C	Inter-Integrated Circuit
IMU	Inertial Measurement Unit
kg	Kilogram
LED	Light Emitting Diode
MP	Medulloblastoma Patient
MP WO FB	Medulloblastoma Patient without Feedback
MP W FB	Medulloblastoma Patient with Feedback
MPU	Motion Processor Unit
MVN	Metabolomics Analysis and Visualization Engine
MTw	Motion Track Wireless
ROM	Range of Motion
S2	Sacral Second Vertebra
TBI	Traumatic Brain Injury

T8	Thoracic Vertebra
UV-Lights	Ultraviolet Light

SUMMARY

Biological feedback, which favors motor control in static and dynamic tasks via augmenting motor information for improving balance and performance, is used to assist patients and clinicians during physiotherapy and rehabilitation practices. Lack of postural control and balance has the greatest impact on patients' mobilization and independent performance during the daily living activities. Although an individual's "static" balance is acceptable while standing still or performing just one task, "dynamic" balance problems may appear during mobilization or while doing multiple tasks at a time. Therefore, being aware of the real-time dynamic balance of the patient is critical for both the patient and the physiotherapist. This investigation developed a real-time tactile biological feedback mechanism intended to be used during the orthopedic and neuromuscular disease rehabilitation practices with the intention of increasing patient motivation, duration and effectiveness of therapy. The preliminary effectiveness of the wearable sensor was investigated on pediatric brain tumor (medulloblastoma) patient's kinematic parameters. As a result, pearson correlation coefficient of the medulloblastoma patient ($r^2_{MP\ WO\ FB}$=0.94, $r^2_{MP\ W\ FB}$= 0.99) and healthy participant ($r^2_{CS\ WO\ FB}$=0.98, $r^2_{CS\ W\ FB}$= 0.99) of the knee joint angle was significantly similar. Paired t test results also revealed a significant similarity in knee joint range of motion in patients with medulloblastoma (61.9 degrees ± 3.4 SD vs. 54.8 degrees± 1.7 SD; t (0.05,29) = 10.2, p <0.001). It was found that the device did not cause a statistically significant change in knee kinematics of healthy participant and did not disturb walking pattern (71.9 degrees ± 2.2 SD vs. 72.8 degrees ± 0.9 SD; t (0.05,29) = -1.8, p = 0.08).

Keywords: Accelerometer**,** Balance, Biological feedback, Biofeedback, Gyroscope, Medulloblastoma, Feedback, Pediatric brain tumor patient, Posture, Real-time feedback, Right knee joint range of motion, Sternum, Tactile, Visual feedback, Wearable motion analysis system, Xsens Awinda.

ÖZET

Giyilebilir, Anlık ve Dokunsal Biyolojik Geribildirim Verebilen Denge Sensörünün Geliştirilmesi ve Beyin Tümörlü Pediyatrik Hasta Üzerinde Pilot Uygulama Testlerinin Yapılması

Denge ve performansın iyileştirilmesi için motor bilgilerinin arttırılması yoluyla statik ve dinamik görevlerde motor kontrolünü destekleyen biyolojik geri besleme, rehabilitasyon sırasında hastalara, fizik tedavi ve rehabilitasyon uzman doktorları ile fizyoterapistlere yardımcı olmak için kullanılmaktadır. Postürel kontrol ve denge eksikliği, günlük yaşam aktiviteleri sırasında hastaların mobilizasyonu ve bağımsız performansları üzerinde en büyük etkiye sahiptir. Bir bireyin "statik" dengesi, sabit dururken veya bir seferde tek bir görevi yerine getirirken kabul edilebilir olsa da; “dinamik” denge sorunları, mobilizasyon sırasında veya bir seferde birden fazla görev yaparken ortaya çıkabilir. Bu nedenle, hastanın gerçek zamanlı dinamik dengesinin farkında olmak hem hasta hem de uzman doktor ile fizyoterapist için önemlidir. Bu araştırmada, ortopedik ve nöromusküler hastalıkların fizik tedavi ve rehabilitasyonu sırasında kullanılmak üzere tasarlanan dokunsal ve görsel biyolojik geri bildirim mekanizması geliştirilmiştir. Giyilebilir sensörün pediatrik beyin tümörü (medülloblastom) hastasının kinematik parametreleri üzerindeki etkinliği belirlenmesi amacıyla ön çalışma tamamlanmıştır. Sonuç olarak, pearson korelasyon katsayıları hastanın ($r^2_{MP\ WO\ FB}$=0.94, $r^2_{MP\ W\ FB}$= 0.99) ve sağlıklı katılımcının ($r^2_{CS\ WO\ FB}$=0.98, $r^2_{CS\ W\ FB}$= 0.99) diz eklem açısı önemli ölçüde benzerlik göstermektedir. Bağımlı örneklem t testi sonuçları da medulloblastoma hastasında diz eklem hareket açıklığında önemli ölçüde benzerlik olduğunu ortaya koymaktadır (61.9 derece ± 3.4 SD vs. 54.8 derece ± 1.7 SD; $t_{(0.05,29)} = 10.2$, $p<0.001$). Cihazın sağlıklı katılımcının diz kinematiğinde istatistiksel olarak bir değişikliğe sebep olmadığı ve yürüyüş paternini bozmadığı tespit edilmiştir (71.9 derece ± 2.2 SD vs. 72.8 derece ± 0.9 SD; $t_{(0.05,29)} = -1.8$, $p=0.08$).

Anahtar Kelimeler: Anlık geribildirim, Biyogeribildirim, Biyolojik geribildirim, Denge, Geribildirim, Giyilebilir hareket analizi sistemi, Görsel geribildirim, İvmeölçer, Jiroskop, Medülloblastom , Pediyatrik beyin tümörü hastası, Postür, Sağ diz eklemi hareket açıklığı, Sternum, Titreşim, Xsens Awinda.

1 INTRODUCTION

The success of the physiotherapy and rehabilitation program depends on its patient- specific design, the ability to keep the patient's performance at the optimal level during therapy, the ability of the patient to adapt to treatment, the experience of the rehabilitation team, and the team's ability to monitor the physical development of the patient instantly and accurately. During conventional rehabilitation, clinical evaluation tools as well as physical examination findings, patient subjective feedback, joint range of motion, and muscle strength measurements do not provide quantitative assessment of joint motion biomechanics, patient mobility, and instantaneous improvement compared to previous therapy results. For this reason, it is very important to support conventional neurologic and orthopedic rehabilitation practices with innovative engineering applications to enable the clinical management of the rehabilitation processes of neurological, neuromuscular and orthopedic diseases for leading to a more effective maintenance and improving the life standards of the patients.

In today`s world, humanity is still seeking for what is best for whatever they do. Awareness of the faults is the main elements in the pathway to progress. Cause and effect relationship is processed with brain via feedback to understand how mistakes are made. Not only in life but also in technology and healthcare innovation, biological feedback covers a broad area in order to make physiological systems to operate better and more efficient. Biofeedback is implemented to human’s life in various areas such as sports, occupational biomechanics and physiotherapy and rehabilitation. This study aimed to develop an innovative wearable balance sensor, capable of providing real-time stimulus for maintaining balance and postural control, and investigate the biomechanical and physiological changes of a pediatric brain tumor patient in response to tactile biofeedback.

1.1 Biofeedback

Biological feedback is used to increase the motivation and performance of the individual during physiotherapy rehabilitation (1). It is a technique of providing instantaneous physiological data, as a stimulated auditory, visual or tactile feedback to enhance the efficiency of the activity performed by the individual by modifying the participant's motivation, concentration, attention and reducing anxiety, disruptive mental problems (2). Biofeedback has been utilized for many years in assisting patients and clinicians during rehabilitation. This method is based on biomechanical measurements and measurements of the physiological systems of the body. The use of information technology is integrated into sports and rehabilitation; hence the quantifiable information is used in designing personalized programs catered for physiotherapy rehabilitation that aim to bring out the best possible outcome. Additionally, the awareness of the immediate condition increases the learning ability, adaptability and willingness to keep with the physiotherapy rehabilitation (3). Also, it allows the athlete or patient to match the data produced by the body with the biomechanical information such as energy consumption, postural control and balance. It is used to minimize the risk of injury, enhance performance and motor skills by balancing the physical and mental routine (4). In the literature, it is stated that motor skill acquisition level of athletes enhances significantly when biological feedback is provided (5).

Measurements of movement, postural control and forces produced by the body are typically involved in biomechanical biofeedback applications. Inertial sensor parameters are used as input to utilize a feedback system that delivers a wide variety of forms of feedback to the user including, auditory, visual and tactile signals. The role of inertial based sensing biofeedback in balance training has been investigated lately. Gyroscopic measurements are used to provide biofeedback and found to make significant changes in trunk angular displacement in both young and older participants during balance tasks compared to control treatment. Movement or behavior may be altered by sensor-based feedback. For instance, individuals can use instantaneous feedback of tibial acceleration from an accelerometer to reduce loading on their lower extremities while running and they can maintain the reduction for at least ten minutes after the feedback is removed.

1.2 Balance

Proprioception is the motion, equilibrium and position sense of the body in space to stabilize the posture via biological information from various visual, vestibular and proprioceptive inputs (6). Static proprioceptive information involves the control of postural orientation; on the other hand, dynamic proprioceptive information involves the control of postural stability (7). An accurate awareness of this information is required for maintaining an upright loading and sustaining normal ambulation.

Organs such as eye, inner ear, and body-position senses trigger impulses which brain interprets and coordinates. The brain makes some adjustments to maintain balance. If one or more of the senses fail to transmit correct signals to the brain, or the muscular system cannot perform the movement necessary, one may not be able to uphold or normalize his balance. Struggling to maintain balance also makes it hard for the person to remain in a stable and upright position while walking, standing and sitting. Balance problems cause tripping, swaying, stumbling, dizziness, vertigo, and falling. Although a person's "static" balance may be proper when standing still or only performing a one task at that moment, "dynamic" balance problems may be visible when the person is ambulating, performing multiple tasks or when there is insufficient lighting in the environment (8). Gait symmetry is described as a ratio of the kinematic and kinetic parameters between the right and left extremities. Symmetrical gait is essential for efficient dynamics, kinematics and kinetics during ambulation (9). Lack of symmetry results in differences in muscle contraction, balance and biomechanics between the sides of the body; therefore, it is one aspect highlighted as a risk factor for possible injuries. Postural control and balance is essential for effective training.

1.3 Posture

Posture is a position that defines the relationship of body parts to each other and body gravity line (10). The fixed posture refers to the posture of the body as static, while the combination of continuous motion patterns creates dynamic posture. Posture can also be defined as the positions taken by the body in preparation of movements. When the body obtains a static or dynamic posture, it provides the balance of the relationship between the gravity line and the center of gravity. In other words, the forces acting on the body balance each other. In this case, as in standing upright, the forces from the ground and body weight balance each other, so the person can maintain the static posture. Likewise, when moving to the next movement, it is possible that the body can adapt and maintain its balance by controlling the forces acting on it. Principles that are necessary to ensure balance are written below:

- Broad support area is needed.
- Center of gravity of the body should be close to the support area.
- Passage of the body gravity line through or near the center of gravity is necessary.
- The body's gravity line must fall into the support area.

The body gravity center in the standing posture, which is considered to be the point where all of the forces acting on the body balance each other, is positioned 2-2.5 cm anterior of the sacral second vertebra (S^2). This location changes depending on the position of the body (11).

Posture is accepted normal or proper if there is no asymmetrical position or any deformation in the body. Posture is defined as normal or proper if the joints confront the minimum level of stress and energy. The position of pelvis is a key element in maintaining and keeping proper posture, the posture said to be proper when it is 140 degrees in the lumbosacral angle and 30 degrees in pelvic and sacral angles (12).

There may be several reasons that can affect proper posture. The evaluation of posture is done by the amount of deviation from normal. The relation in between body parts and the gravitational line are compared with normal anatomical features resulting as deviations and differences are determined.

Proper posture can be defined as when joints are under minimum pressure. This depends on the characteristics of the musculoskeletal system as well as the systems that provide postural control such as strong muscle structure, flexible muscles and ligaments and firm joint control. Having adequate flexibility in muscle, tendon, ligament, joint capsule and surrounding connective tissue, strong joint control and sturdy and stable muscles are required in order to maintain the posture and respond to changes. While these features may be provided, they are not always enough. Even if they allow proper posture, because of the variety of properties that affect and change the posture immediately or over time. Orthopedic diseases, neuromuscular diseases like Traumatic Brain Injury (TBI) and neurodegenerative diseases such as brain tumors are some of them.

1.4 Balance and Postural Control Impairment of Brain Tumor Patients

According to the Central Brain Tumor Registry of the United States, from 2002–2006 the incidence rate of childhood brain tumors (ages 0–19 years) was 4.74 per 100,000 person-years (13). Medulloblastomas, are 20% of all pediatric brain tumors being second in most common pediatric brain tumor types, are the most common malignant brain tumor of pediatric population (14-16).

Pediatric brain tumor treatment is employed in different methods such as anti-angiogenic agents, biologically targeted methods, high-dose chemotherapy with autologous hematopoietic cell rescue, chemotherapy, radiotherapy and surgical resection (17). Children with brain tumors may face a broad range of functional problems due to the effects of primary lesion and complications of treatments. Impairments extent and its nature may depend on development level of child during the period of diagnosis, child's age, lesions location and the neurologic compromise degree. Apart of effects in cognition, in the literature, there is lack of information related to rehabilitation of children with brain tumors. The most common types of brain tumors in pediatric population are gliomas and medulloblastomas (Figure 1.1).

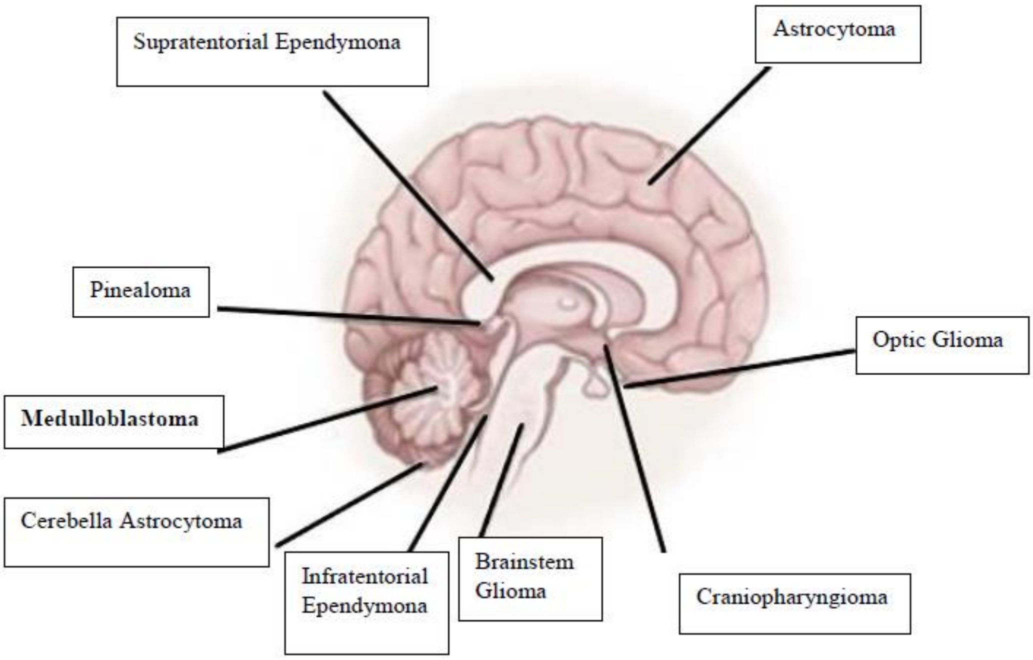


Figure 1.1 Pediatric Brain Tumor Classifications (adapted from https://www.hopkinsmedicine.org/neurology_neurosurgery/centers_clinics/brain_tumor/center/pediatric/tumors/, Date of Access: 05.04.2019)

For optimization of functional independence, rehabilitation program should be created which is in need of appropriate goals identifications and rehabilitation care phases with a clear communication with the patients and her/his family about the realistic goals. The treatment itself and its effects should be considered while developing a rehabilitation plan of children with brain tumors (18).

Proprioception and sensation should be evaluated and complaints such as neck pain or back pain due to poor posture or underlying core muscle weakness' should be remarked and evaluated. Pain refractory to physiotherapy rehabilitation should be re-evaluated taking possibility of metastases into account (19). According to the studies up to date, depression is also related with survival time of patients with brain tumors. A study of 75 patients with solitary brain tumors showed that the patients with low-grade gliomas, who were depressed, had shorter post-surgery survival times compared with the ones who were not classified as depressed (20).

Pediatric brain tumor patients experience decrease in their quality of life after treatment due to their psychomotor problems and altered motor functions (21,22). Pediatric patients, who suffer from brain tumors, encounter weakness and fatigue and also difficulties in coordination and balance problems while performing daily living activities, and these not only affect their motivation, but also limit their motor abilities, which are of great importance in daily living activities and quality of life (23,24). The absence of gait symmetry results in differences in muscle contraction, balance and biomechanical parameters during mobilization, and therefore causes possible injuries (25). A complex integration and relation of a variety of body systems required for balance and they need to be intact for full functioning (26). It is a common knowledge that lesions to the cerebellum cause ataxia or balance loss and alterations in coordination but in literature the functional impact of lesions to different parts of cerebellum has been only recently described. The damage to vermis and deep cerebellar nuclei are highly related with balance control decrease more than age or tumor size (27).

As a result, with improvement in physical, physiological and cognitive status, the adaptation of the body to physical activities can be achieved. According to recent investigations, biological feedback applications stated as beneficial tools for neurological, neuromuscular and orthopedic diseases' motor rehabilitation practices. Feedback based treatments encourage participation and motivation, improves healing process of motor functions more effectively compared to the conventional treatments. Okada K, Imaizumi T, Hirabayashi K, Matsuyama M, Yazawa N, Dowaki S, Tobita K, Ohtani Y, Kawaguchi Y, Tanaka M, Inokuchi S, Makuuchi H (2010) showed that real time visual center of gravity (COG) feedback improves postural control. Similarly, combination of conventional rehabilitation with biological feedback applications, rehabilitation of neurological diseases is improved better compared to the conventional treatments. Ribeiro IMA, Drews M, Bahl A, Machacek C, Borst A, Dickson BJ (2018), showed that with electromyographic feedback, dysphonia patients' voice treatment was improved with facilitating more effective muscle electrical activity. These determinations show that biological feedback is one of the best methods for providing real time and consistent information about physiological, biomechanical and proprioceptive status of the patient.

The success of physiotherapy rehabilitation program is related with being specific to person, keeping the performance in optimum level during therapy, adaptation of patient to treatment, experience of rehabilitation team and traction of patients' physical evaluation real time and accurately. During conventional rehabilitation process, physical diagnostics are done via evaluations with scale of patients' subjective feedback, joint range of motion (ROM) measurements, muscle strength and functional status investigations, where quantitative information is obtained and provided neither to the patient nor the physiotherapist. This makes it difficult to arrange personalized physiotherapy rehabilitation programs and increase the duration of the effective physiotherapy rehabilitation sessions.

Especially in pediatric population and/or people suffer from depression, visual biofeedback increases motivation and improves cognitive skills; also supports a better level of involvement and attention of the patient during physiotherapy rehabilitation. Innovative technology can instantaneously show the progress of the patient's mobility, by providing a fun and motivating environment for the patient by enabling the mobility situation to be instantly determined and a more effective and personalized rehabilitation plan can be determined. The conventional methods cannot provide the patient or physiotherapist the ability to transfer the instantaneous and quantitative mobility capacity of the patient and improvement obtained compared to the previous therapy results. This causes both the patient's motivation not to be at the optimal level and the rehabilitation team's inability to determine the personalized and the most effective physiotherapy rehabilitation program for the patient.

The innovative real time balance biofeedback mechanism was used in brain tumor physiotherapy rehabilitation session to identify the system's potential of correcting patient's balance and regulating the movement pattern during standard 10 meters walking test at self-selected walking speed and single-leg stance assessment tests with and without tactile biofeedback.

The aim of this innovative study was to compare the clinical, biomechanical and functional efficacy of conventional physiotherapy rehabilitation with gait training, which was supported with biofeedback mechanisms, on pediatric brain tumor

(Medulloblastoma) patient mobilization and develop innovative, personalized and effective rehabilitation programs.

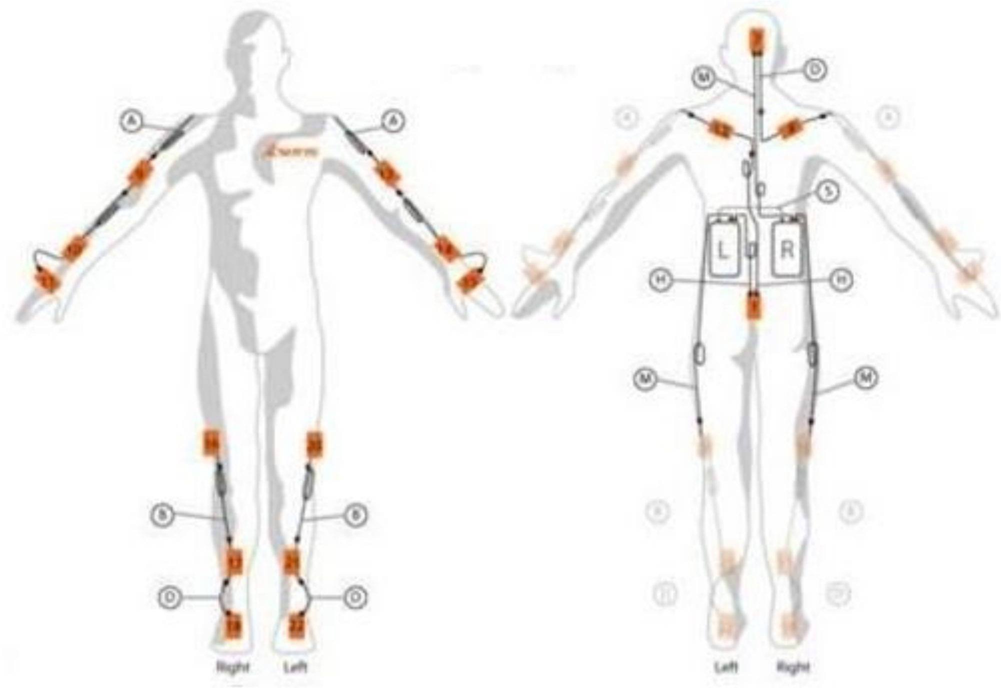
2 EQUIPMENT & METHODS

2.1 Equipment

2.1.1 Xsens 3D motion tracking system

Xsens (Xsens Technologies BV®, The Netherlands) is a portable inertial motion capture system for full body motion analysis. The system consists of 17 wireless sensors (Figure 2.1.a), (MTw2, range of measurement of angular velocity: ±1200 °/s, sampling rate: 100 Hz) which comprise accelerometer, gyroscope and magnetometer, are attached to the key areas of the axial and appendicular body (Head, Left and Right Shoulders, Sternum, Left and Right Upper Arms, Left and Right Upper Arms and Left and Right Hands, Pelvis, Left and Right Upper Legs, Left and Right Lower Legs and Left and Right Foot) (Figure 2.1.b). Battery powered sensors communicate wirelessly with the host computer. Real time data is displayed on the main computer screen and this data is recorded for later analysis. The specially developed modular motion trackers are able to detect all activities- from the smallest motion in the body to the dynamic motions, such as knee joint orientation during running. All types of motion are detected by the sensors, and the biomechanical data are collected and recorded in real time. Thanks to its wireless design, it provides a fast and easy installation and allows motion analysis to be done in the desired environment. Inertial sensors are useful in movement and balance cases with the advantage of their small size and portability that also made them be popular recently with the advantage of suitability for use outside laboratory set-up. It allows an unrestricted, 3D and spontaneous gait analysis (28) and has been validated against optical motion capture system (29). It was used in several biomechanical studies (30-32) in the literature.

(a)



(b)

Figure 2.1 (a) Xsens Accompanying Software (Xsens Technologies BV (Netherlands®))

(b) IMU sensor locations (https://www.xsens.com/products/mtw-awinda/, Date of Access: 10.04.2019)

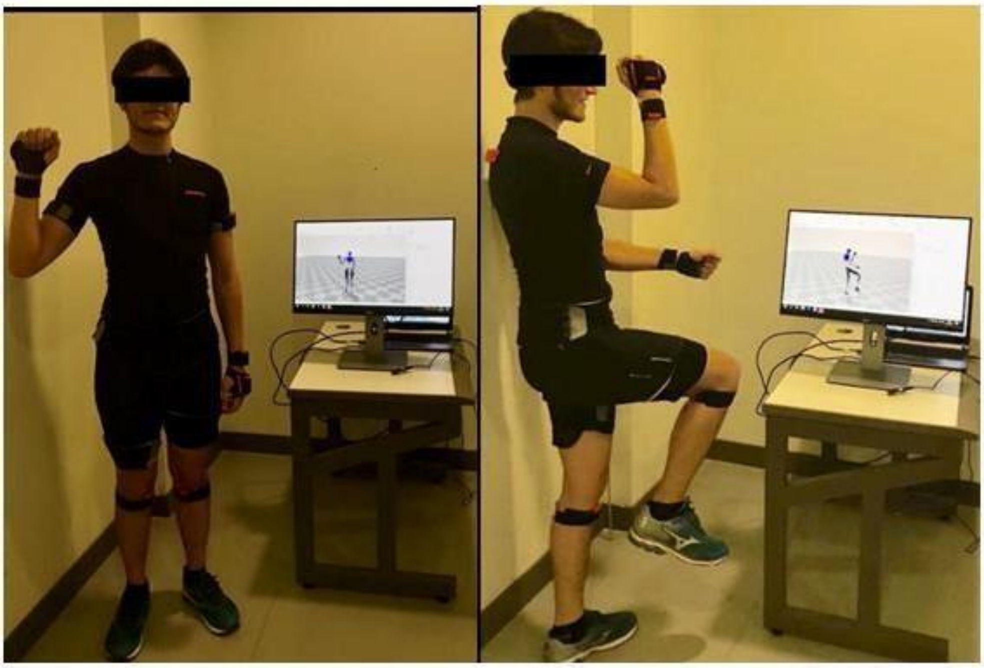


Photo 2.1 Xsens MVN Awinda Mtw Sensors Placement

2.1.2 Wearable real-time balance biofeedback device

A wearable tactile real-time balance biological feedback mechanism was developed, which is intended to be used during the neurological, orthopedic and neuromuscular disease rehabilitation practices and its accuracy and sensitivity were validated with Xsens MVN Awinda wearable motion capture system (Photo 2.1 and Photo 2.2). Patient`s real-time balance was monitored with Motion Processor Unit (MPU) 9250 (9-axis sensor with 3-axis accelerometer, 3-axis gyroscope and 3-axis magnetometer), which was placed on patient’s sternum. All motors and the MPU were controlled by Raspberry Pi.

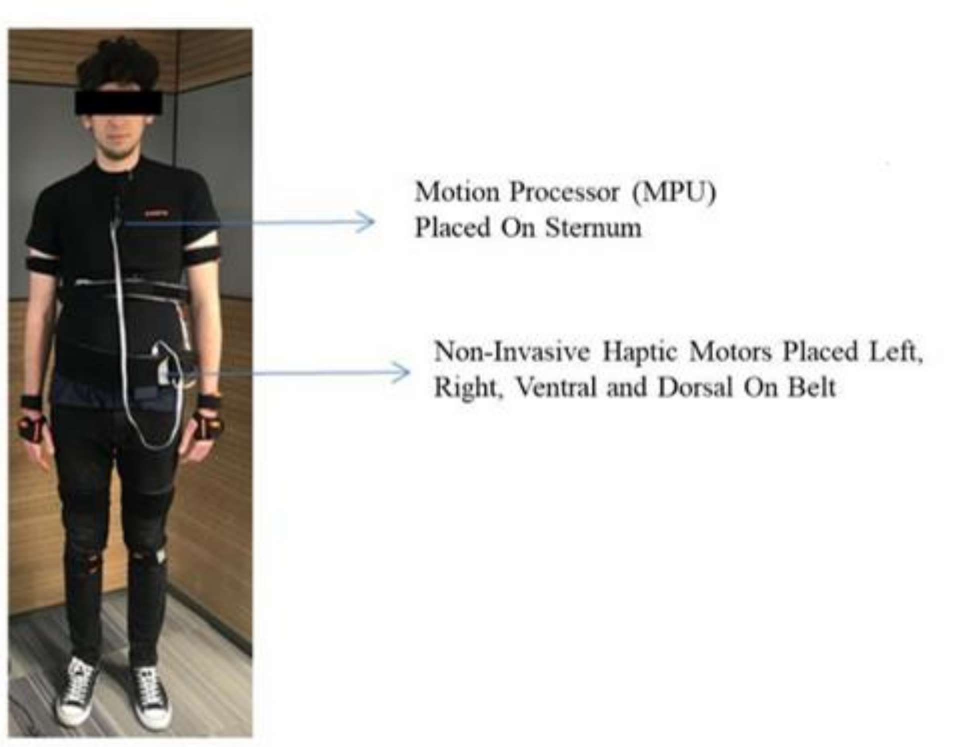


Photo 2.2 Placement of Non- Invasive Sensors over Body, Providing Real Time Haptic and Visual Feedback (shown on healthy subject)

The innovative real-time balance sensor device was composed of a motion processor unit (MPU), microprocessor and four vibration motors. Vibration motors -for front-back- left-right directions, were located between the participant`s under bust and natural waist line with an adjustable strap designed with the loop side of the Velcro material. Accurate positioning of the motors was obtained by using ergonomic 3D printed cases (using stereolithography) attached to the participant’s body with the hook side of the Velcro. Device is designed as wearable which is a combination of a non-invasive belt placed on the belly of the patient and a motion processor (MPU) (3 axis accelerometer, 3 axis gyroscope and 3 axis magnetometer and a 9-axis sensor) placed on sternum (T8 level posteriorly).

The sensor ensures the participant maintains the center of mass of the body in balance, which is the equilibrium, in other words the zero position. Sensor calibration is done while the participant stands still for 3 seconds at the beginning of the session. The sensor requires a threshold value input, which determines the acceptable circular path that the sternum can travel. As the center of mass of the body exceeds this predetermined threshold value, the vibration motors get activated instantly and warns the participant that the balance has been lost through tactile biofeedback. In addition, with the algorithm developed and the LEDs placed over four motors, the information about which motor is giving feedback is gathered that is also a visual biofeedback to the physiotherapist. The location info is gathered by the 9-axis sensor placed on sternum and processed with Raspberry Pi® (Raspberry Pi Foundation, https://www.raspberrypi.org). Calibration process (Figure 2.2), determination of the directions (Figure 2.3, Figure 2.4), counting (Figure 2.5) processes can be seen through the flowchart of this algorithm which is shown as below:

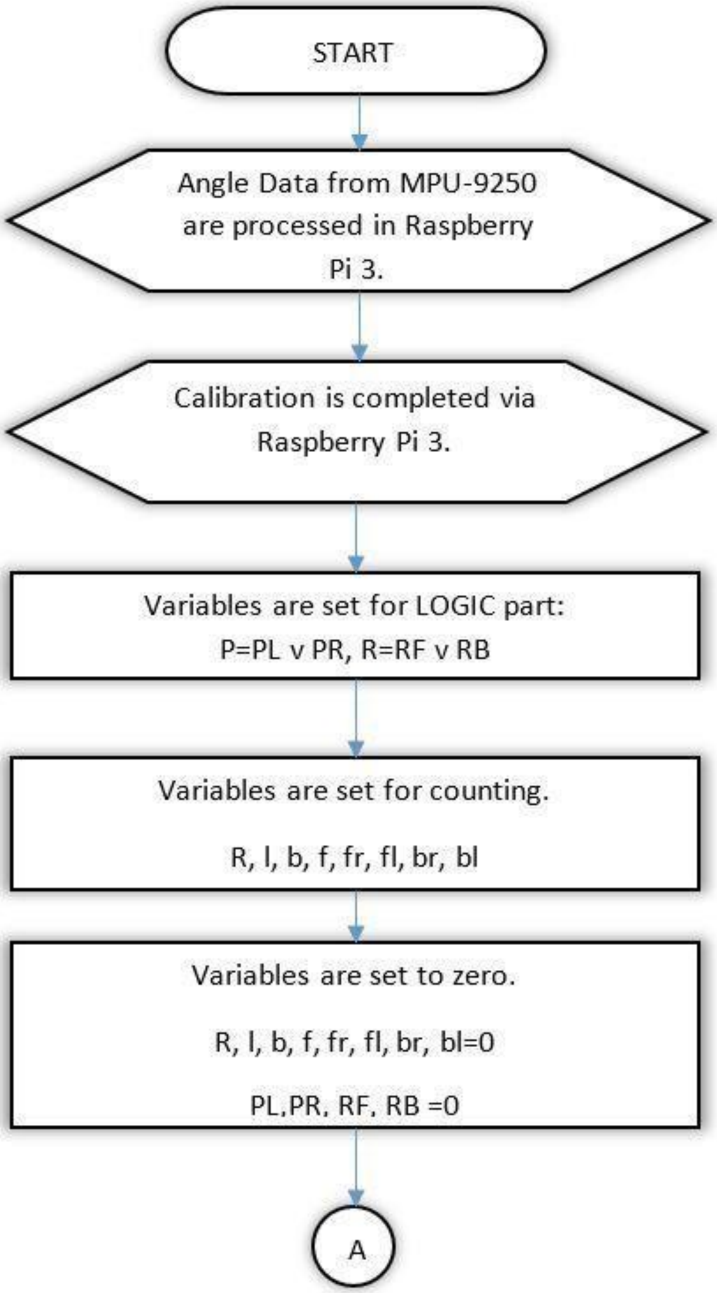


Figure 2.2. Flowchart of the Program Part I: Arrangement of the Settings and Calibration

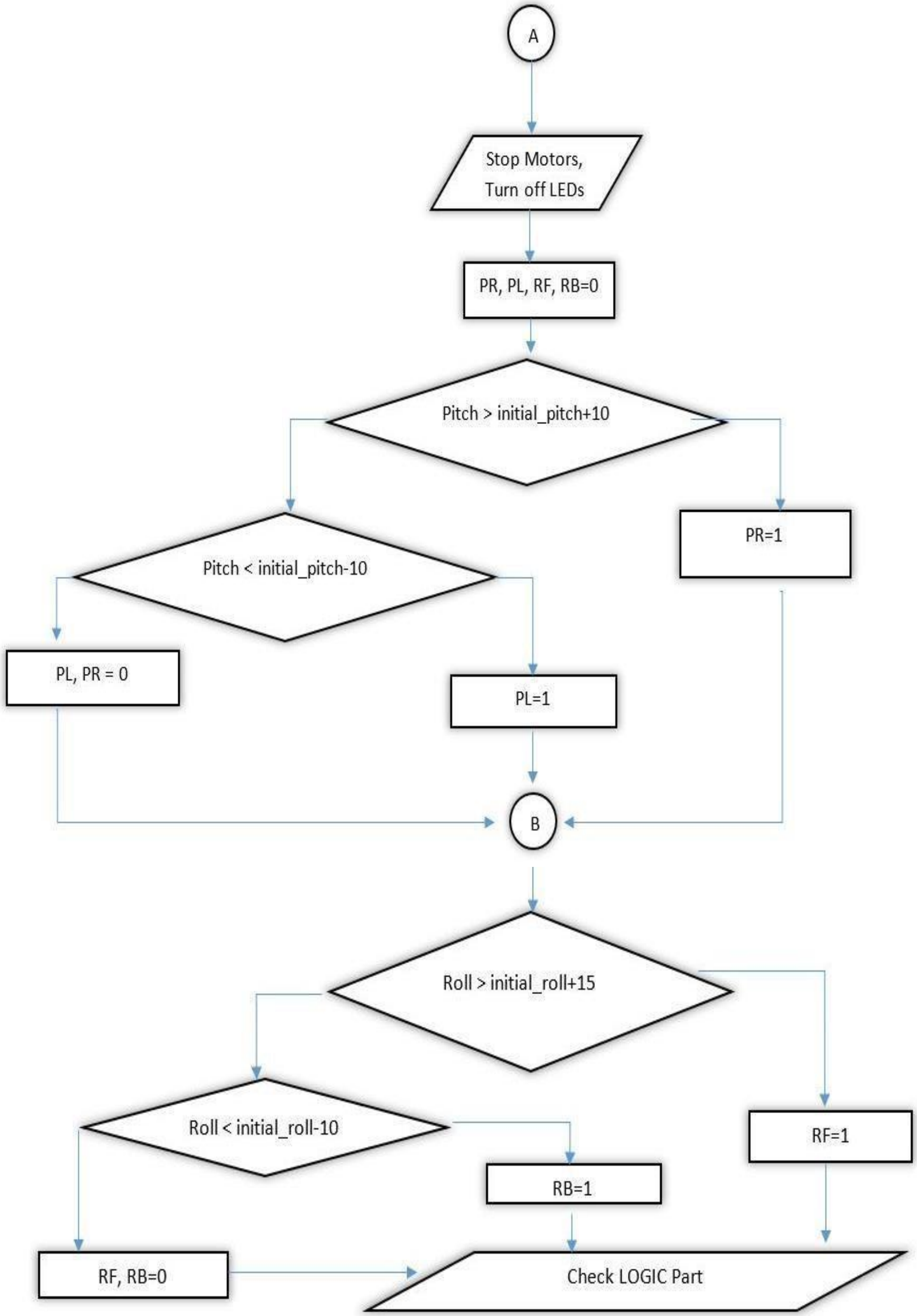


Figure 2.3. Flowchart of the Program Part II: Deciding The Direction of the Disturbance of the Balance

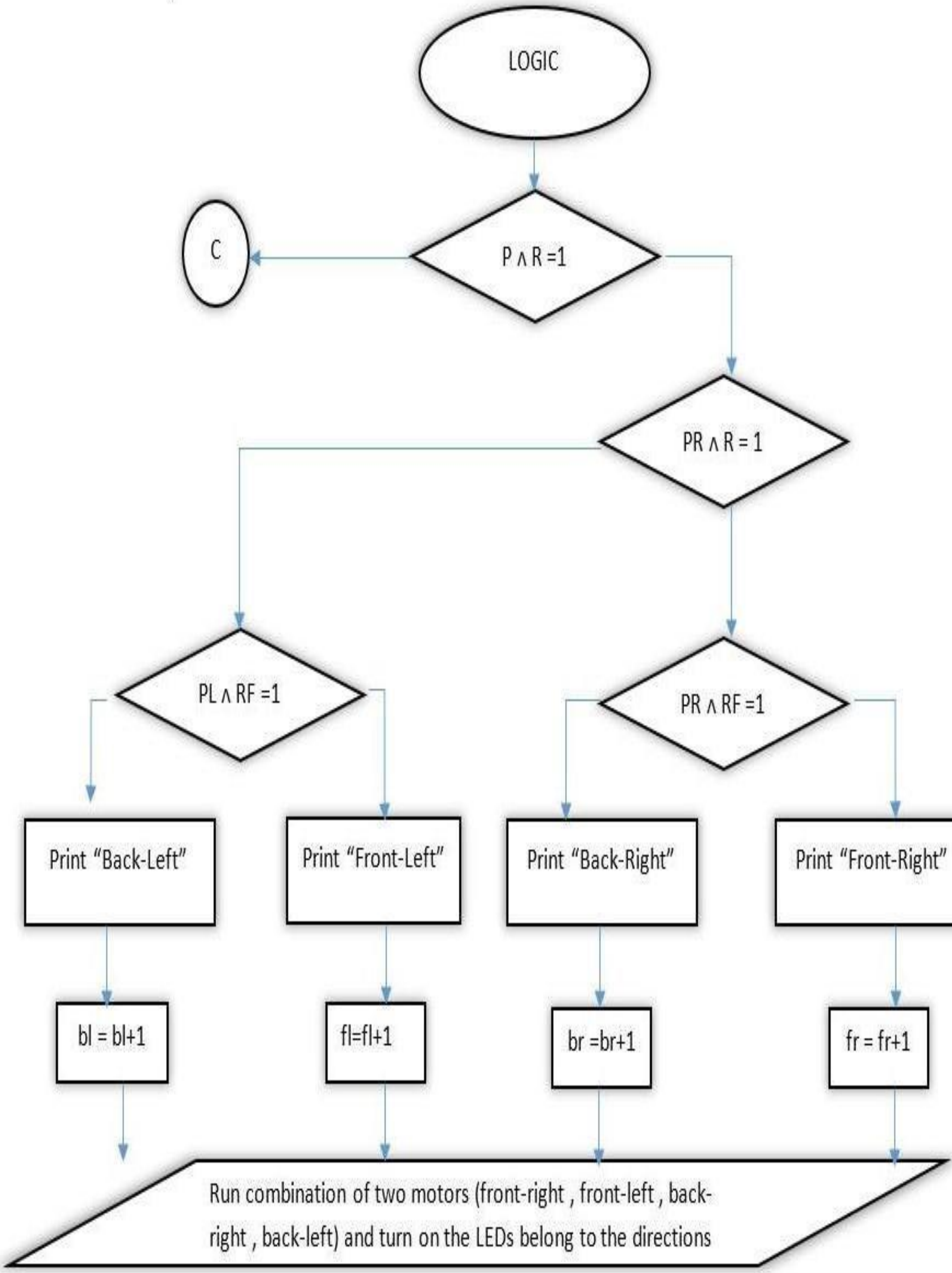


Figure 2.4. Flowchart of the Program Part III: Deciding Whether the Direction Is the Combination of Two Sides or Not

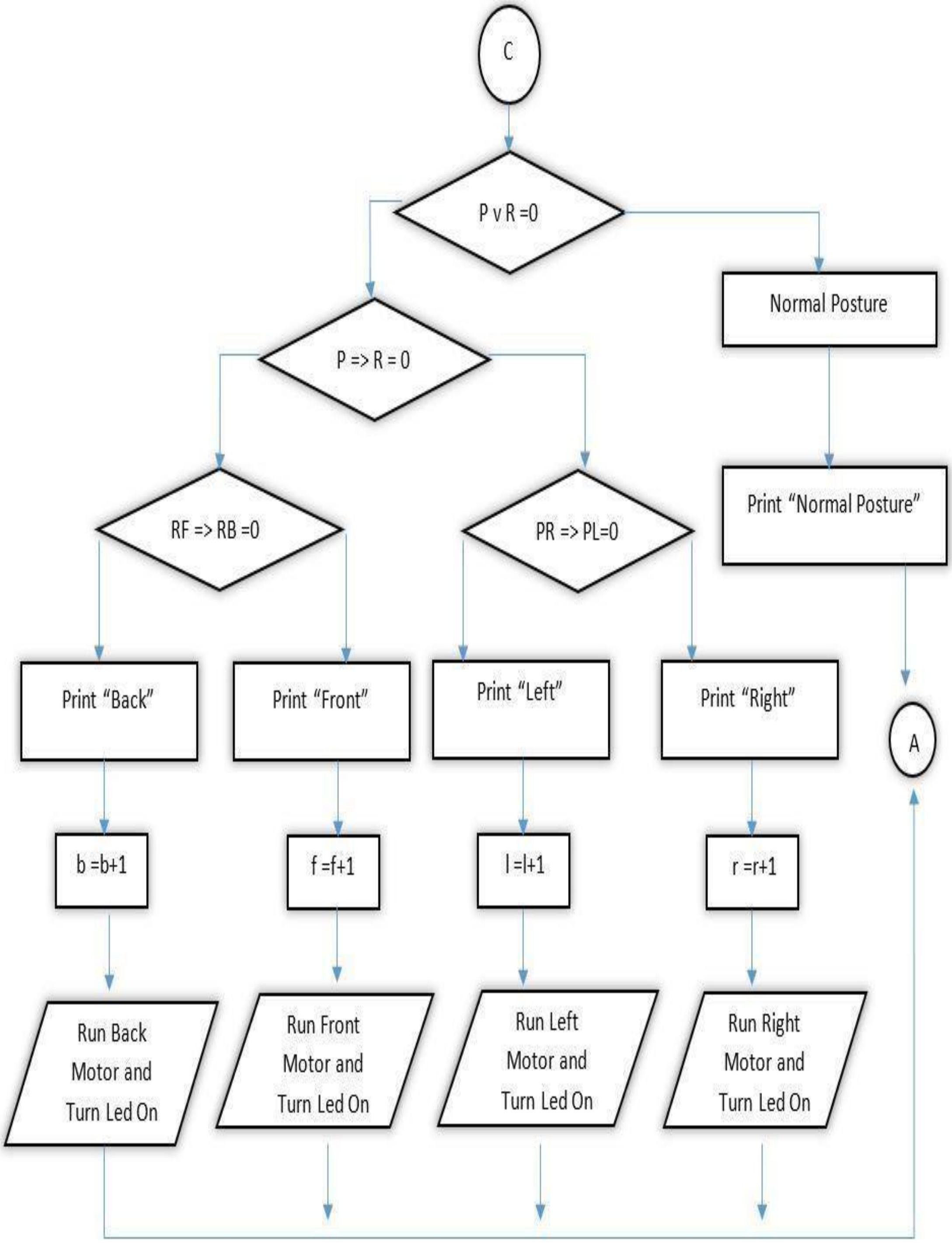


Figure 2.5. Flowchart of the Program Part IV: Counting The Directions

The sensor assumes the axial body as a simple pendulum, sternum being the bob, the amount that the pendulum bob is displaced to the left, right, back or front- or the combination of two- off its equilibrium or rest position (initial calibration value) over the course of time, the corresponding vibration motors (one of the vibration motors in the frontal plane (anterior-posterior directions) and/or the combination of one of the vibration motors in the sagittal plane) get activated and real-time tactile biofeedback is provided to the participant. The sensor sheaths, which were designed with Autodesk Fusion 360 TM CAD (https://www.autodesk.com), were obtained by using the standard black resin with the 3D printer (Formlabs Form 2® (https://formlabs.com). The system was verified with a commercialized state-of-art wearable motion capture system Xsens MVN Awinda.

To be able to get the orientation data, Quaternion variables were converted to Euler Angles. To get proper left and right directions, pitch angles were used and for forward and backward directions, roll angles were used (Figure 2.6).

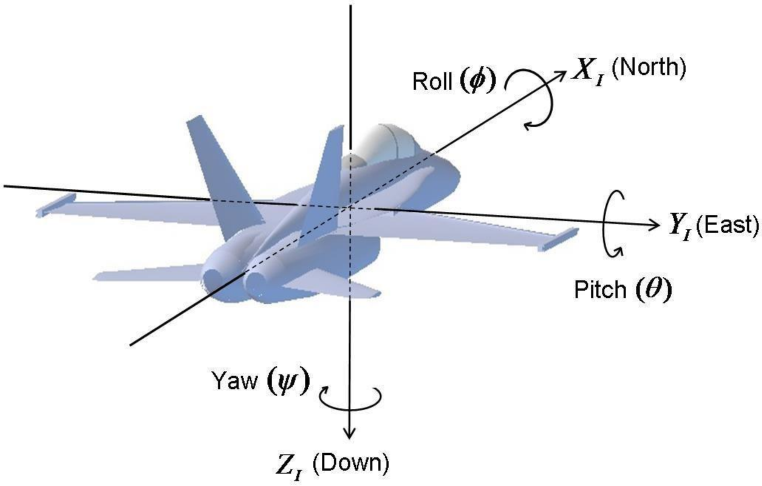


Figure 2.6 Euler Angles Representation

[http://www.chrobotics.com/library/understanding-euler- angles, Date of Access: 16.04.2019]

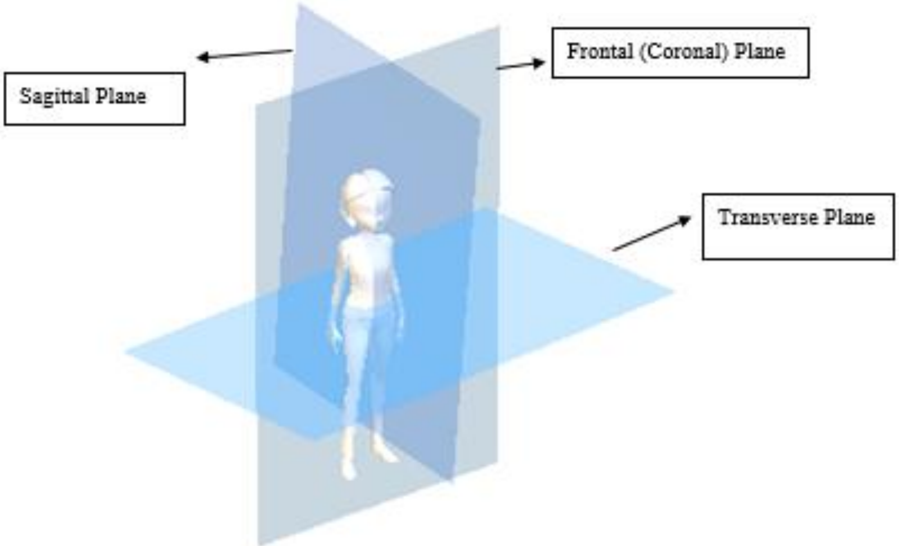


Figure 2.7 Anatomical Planes of the Body

Sagittal plane covers anterior and posterior balance changes and frontal plane covers right and left (Figure 2.7). Horizontal plane represented the sternum origin and the sway trajectory of the body.

As seen in Figure.2.8 Front, Back, Left, Right are defined as main, Front-Right, Front- Left, Back-Right and Back- Left are defined as combination sides.

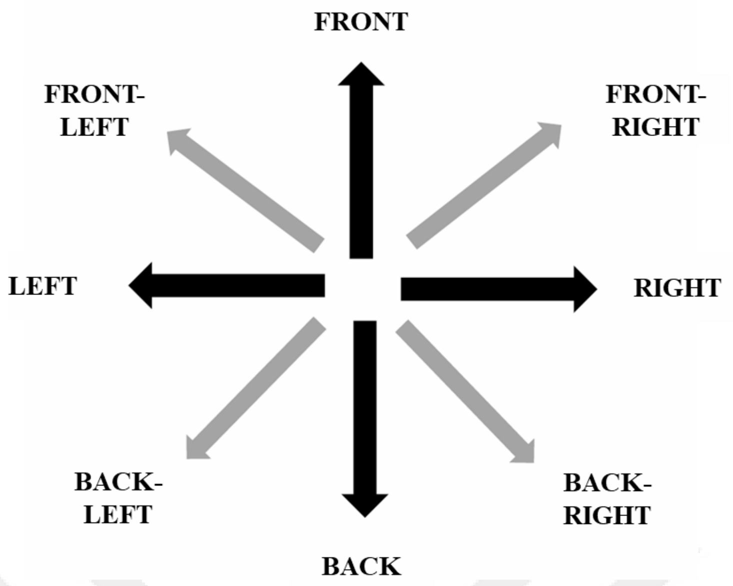


Figure 2.8 Balance Change Sides (Black Arrows for Main Sides, Grey Arrows for Combination Sides)

2.1.2.1 Design

2.1.2.1.1 Design of balance sensor device and biofeedback mechanism

Patient's real-time balance monitored with Motion Processor Unit (MPU) 9250 (Figure 2.9) has 9- axis sensor with 3-axis accelerometer, 3-axis gyroscope and 3-axis magnetometer and placed on the sternum. All motors and the MPU was controlled by Raspberry Pi (Raspberry Pi Foundation, https:www.raspberrypi.org).

Wearable biofeedback device was composed of Raspberry pi 3 Model B, 4 DC haptic motors, 4 LEDs, one 9 axis MPU 9250 sensor (Figure 2.9), 2 motor drivers, powerbank and designed protohead as in Figure 2.10. In order to run 4 DC haptic motors, 2 motor drivers (ULN 2803) were used.

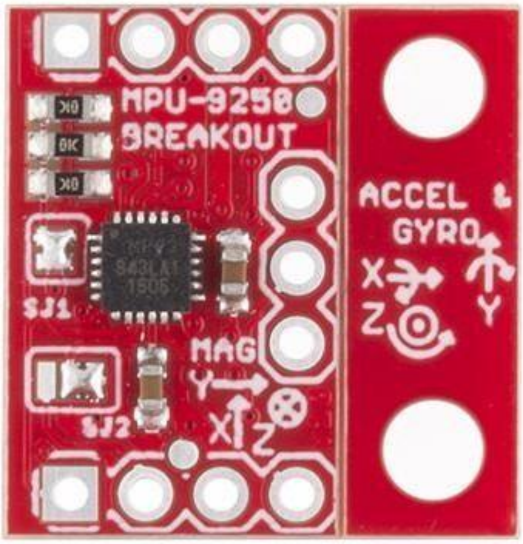


Figure 2.9 MPU 9250 Sensor (IMU (9-Axis) Breakout - MPU-9250)

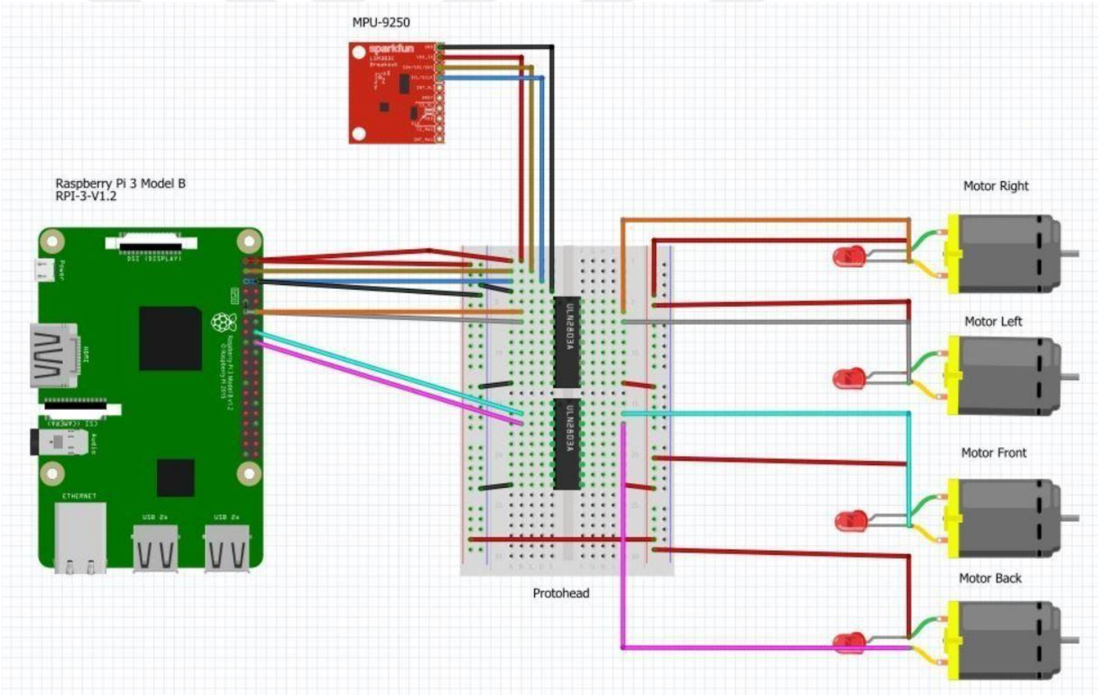


Figure 2.10 Circuit Diagram: Connections Shown with Basic Representations

The ultimate aim was to get accelerator data from MPU 9250 and the obtained data was processed using I2C protocol by Raspberry Pi (Figure 2.11), which was used as microprocessor unit and according to the threshold values and variables (shown in the flowchart shown above), corresponding DC haptic motors were activated, and LEDs were turned on (Figure 2.12).

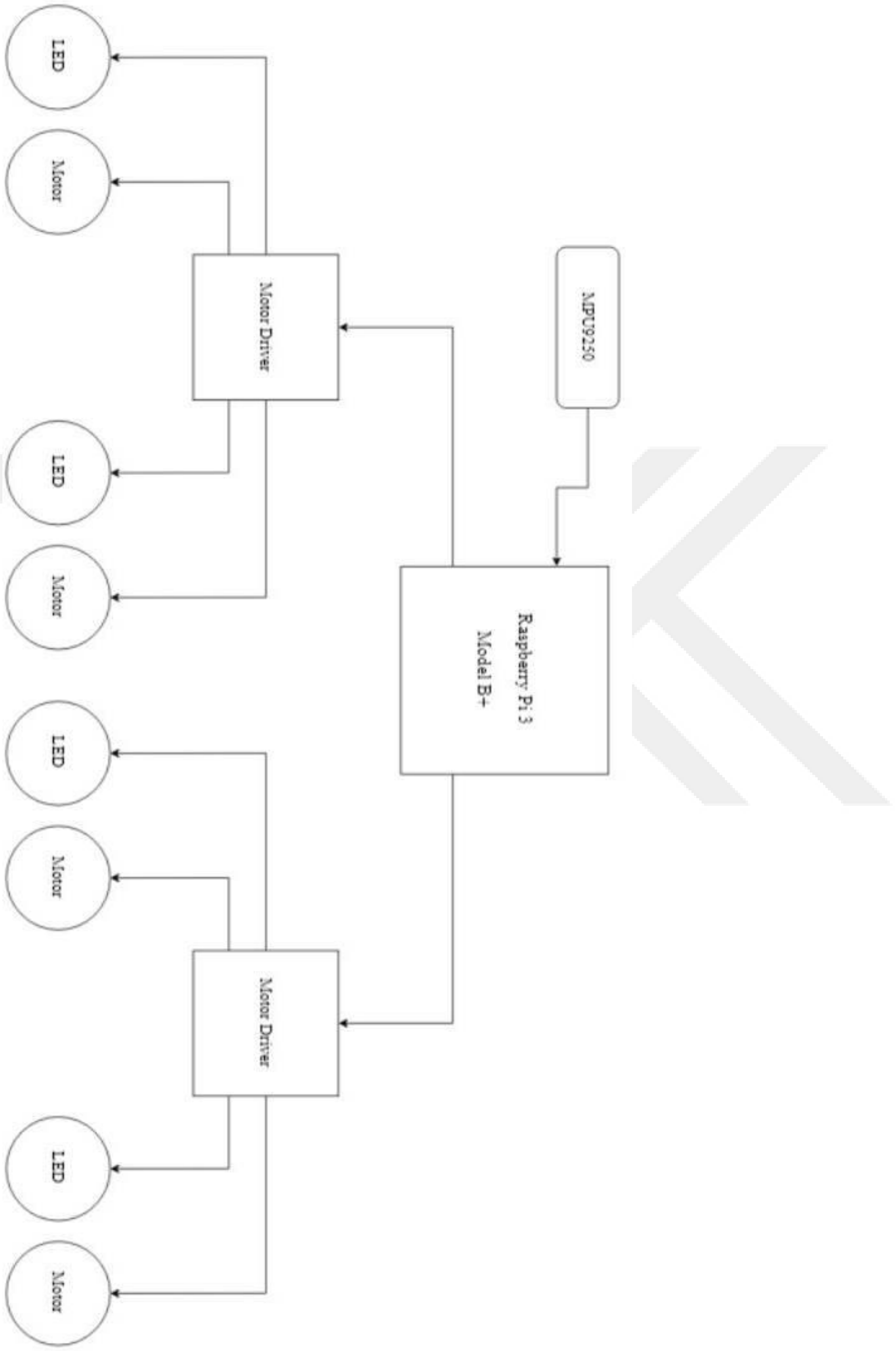
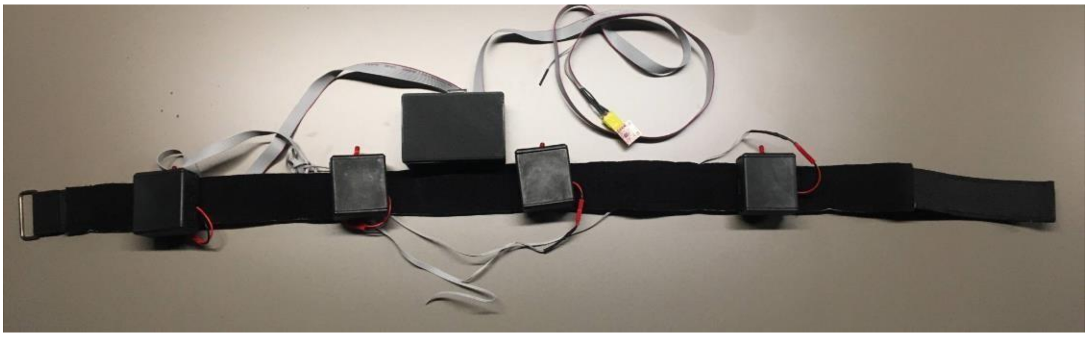
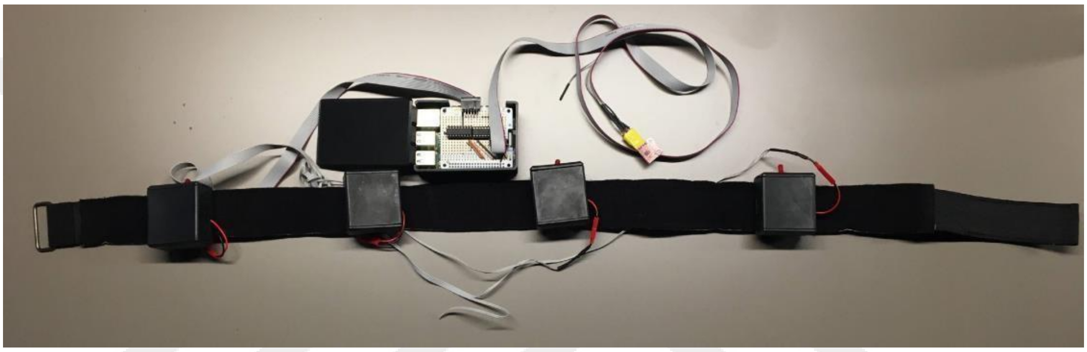


Figure 2.11 Hardware Block Diagram: Brief Summary of the Device



(a)



(b)

Figure 2.12 (a) Closed View **(b)** Opened View of Wearable Real-time Balance Biofeedback Device

2.1.2.1.2 Design of the ergonomic 3D cases for the prototype

The prototype 3D cases, which were designed by Autodesk Fusion 360™ CAD (https://www.autodesk.com.tr/products/fusion-360/overview), printed by Formlabs Form 2® (https://formlabs.com/3d-printers/form-2/) 3D printer using standard black resin, had 25 micrometer height as final version (Figure 2.13). As the final process all parts were post-cured with UV- Lights to obtain the smooth final texture.

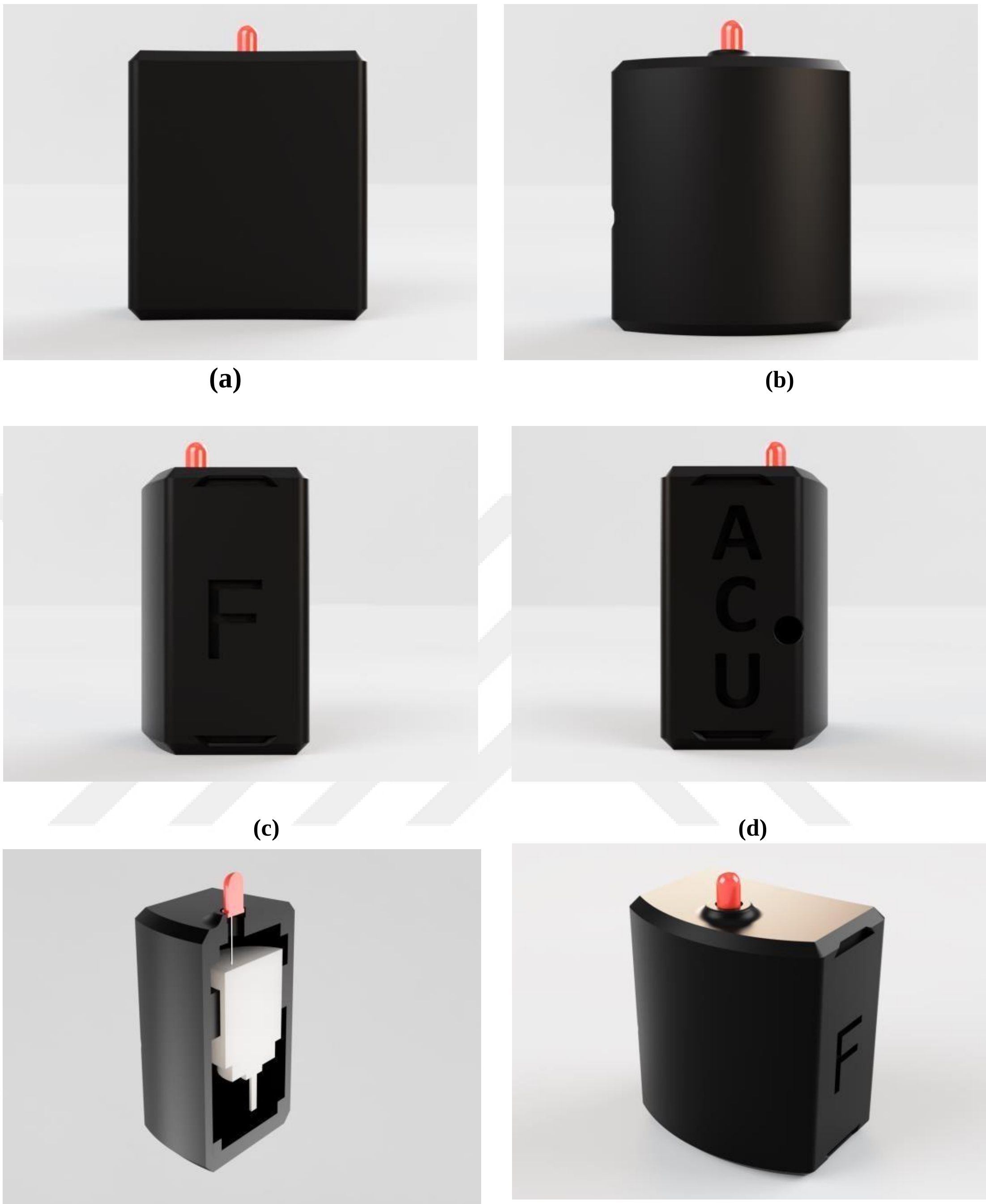
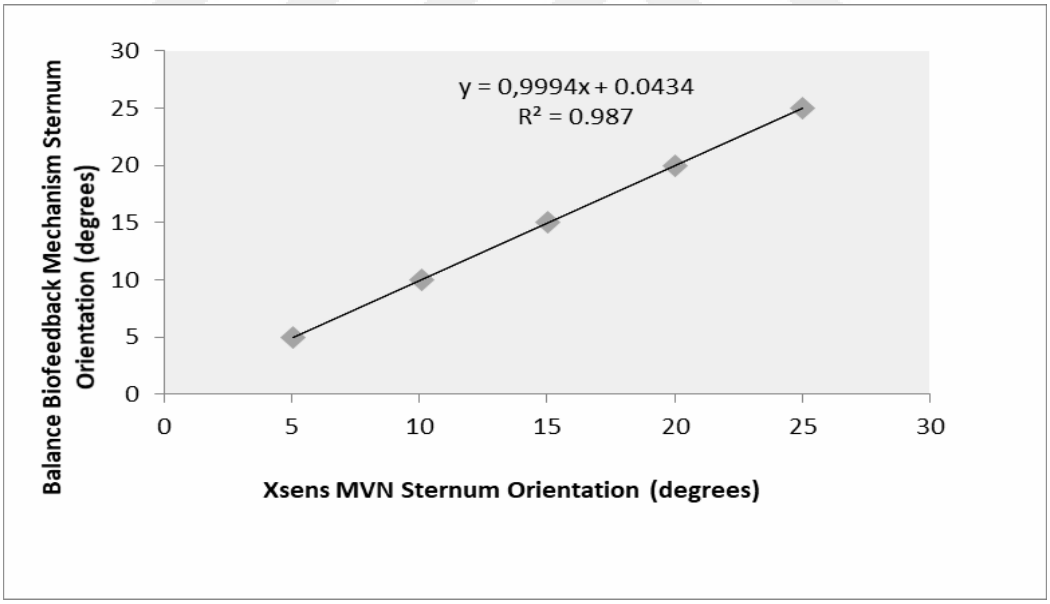


Figure 2.13 (a) Back **(b)** Front **(c)** Left **(d)** Right **(e)** Section **(f)** Perspective Views of Ergonomic Stereolitiography Cases for Haptic Motors Placed Over Belt, Printed by 3D Printer

2.1.2.2 Verification of wearable balance biofeedback device

Real-time balance biofeedback mechanism was validated (Figure 2.14) with Xsens MVN (Xsens Technologies BV® (Netherlands)). Sternum IMU sensor and wearable balance biofeedback mechanism were placed on a healthy subject and the postural alignment was measured at 5-10-15-20 and 25 degrees. Paired t-test was applied in order to investigate the statistical significance between the Xsens MVN readings and the balance biofeedback mechanism at 5-10-15-20 and 25 degrees. 10 readings from Xsens MVN and biofeedback device were obtained at these degrees (Figure 2.15). IBM SPSS Statistics v21.0 was used to compare the output of the two systems. Normal distribution was confirmed and a paired t-test was used to validate the balance sensor readings with the Xsens MVN readings. The results indicated that there was no significant difference between two system readings ($t= 1.91 < t_{(0.025,28)} = 1.72$ $p>0.05$). The balance biofeedback mechanism results correlated significantly with Xsens MVN postural alignment readings ($r=0.99$, $r^2=.98$, $P<.05$; Graph 2.1).



Graph 2.1. Correlation Between Xsens MVN and Wearable Balance Biofeedback Mechanism

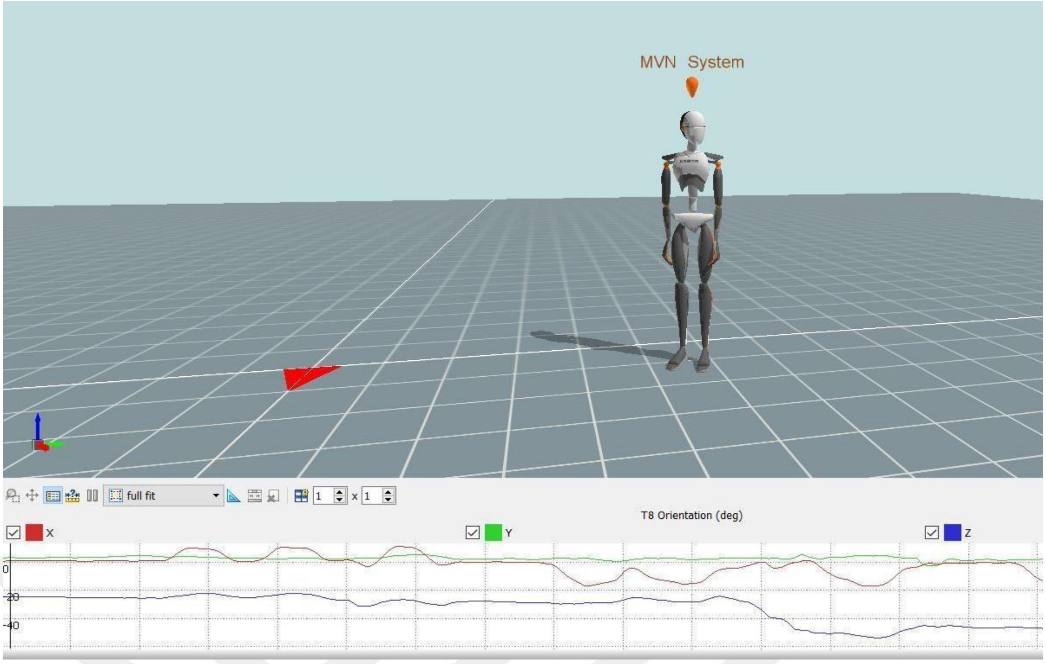


Figure 2.14 Validation Test with Xsens MVN (Postural Alignment with Center of Mass and Sternum Orientation Readings)

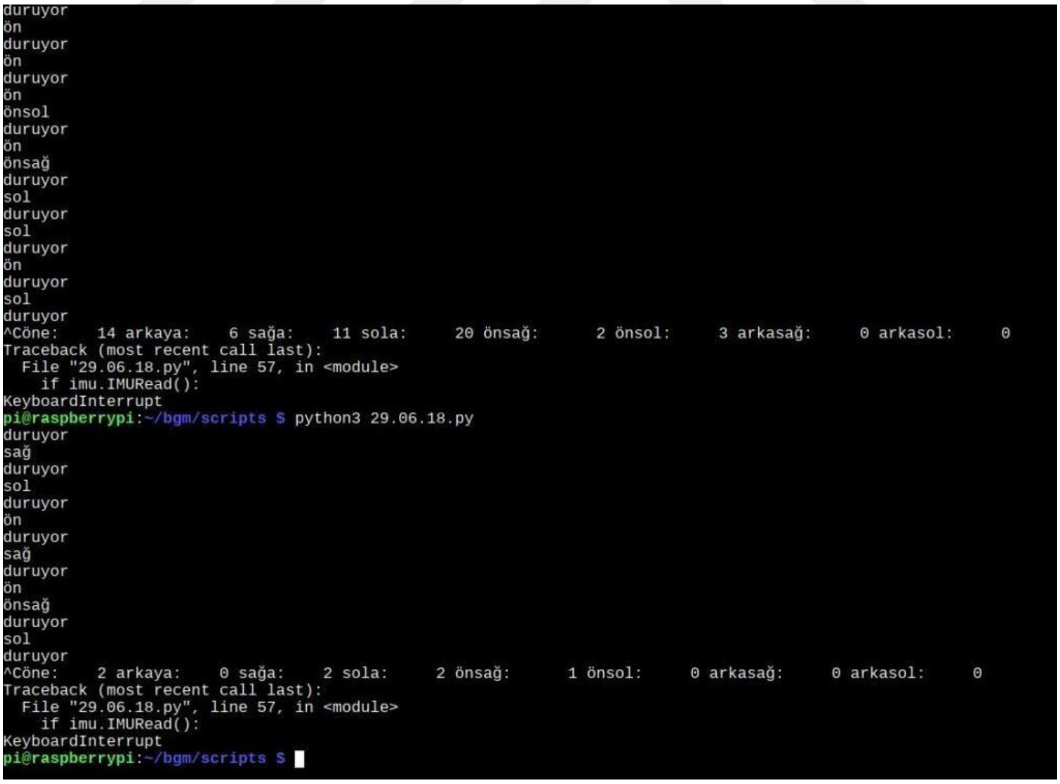


Figure 2.15 An Example of a Balance Control Report of The Patient Obtained at The End of The Physical Therapy Session With Real-time Balance Biofeedback Mechanism

2.2 Methods

2.2.1 Participants

A 16 years old brain tumor (medulloblastoma) patient, (Gender: Female, Height: 149 cm, Weight: 54.5 kg, BMI:23.24, Right dominated), who has undergone surgical intervention, participated in this study. The patient and her parents were informed in advance about the test method and permission was obtained from the patient and her parents for participation in the study. The patient was selected from Bezmialem Vakıf University Faculty of Medicine patient directory, who have been rehabilitated in the Department of Physiotherapy and Rehabilitation at the Faculty of Health Sciences of Bezmialem Vakif University. 16 years old healthy subject (Gender: Female, Height: 167 cm, Weight: 53.2 kg, BMI: 19, Right Dominated) participated in this study as the control subject. Her parents were also informed about the process and permission was obtained from participant and her parents. Medulloblastoma patient participated in training under the guidance of a physiotherapist and data collection was done at Pediatric Physiotherapy and Rehabilitation Laboratory of Bezmialem Vakıf University. Prior to testing, each subject read and signed an informed consent that was approved by the Bezmialem Vakıf University Academic Review Board.

2.2.2 Data Processing

Wearable motion capture system Xsens MVN Awinda (Xsens Technologies BV, The Netherlands) composed of 17 inertial measurement units was used to get the full-body kinematics, sternum (T8) orientation and right knee joint angles of both participants were collected with Xsens MVN and data reduction was done with Xsens MVN Studio 4.2.4. Number of balance loss directions (Figure 2.14) were collected with wearable balance biological feedback device and reported. Heart rates of the participants were measured with Polar H10 (POLAR H10 (Polar, USA), at the beginning and end of the session.

2.2.3 Examination exercises

10 meters walk test at self-selected walking speed for 2 minutes and single leg stance assessment tests were examined while the participants were and were not guided with real- time balance biofeedback.

2.2.3.1 10 Meters walking test

The 10 meters walking test was used to measure performance to assess walking speed in meter per second over a short distance.

Photo 2.1 Control Subject Performing 10 Meters Walking Test with Real-time Balance Biofeedback Device

As one can see from photo 2.1, control subject was performing 10 meters walking test with the designed tactile biofeedback device with and without biofeedback. Medulloblastoma patient (Photo 2.2) was performing the same test with same equipment. Both subjects wore Xsens Awinda to get their kinematic data throughout the test.

Photo 2.2 Medulloblastoma Patient Performing 10 Meters Walking Test with Real-time Balance Biofeedback Device

2.2.3.2 Single leg stance assessment test

Control Subject was instructed to stand on one leg without support of the upper extremities or bracing of the unweighted leg against the stance leg as seen in Photo 2.3.

Photo 2.3 Control Subject Performing Single Leg (Left Leg) Assessment Test with Real-time Balance Biofeedback Device

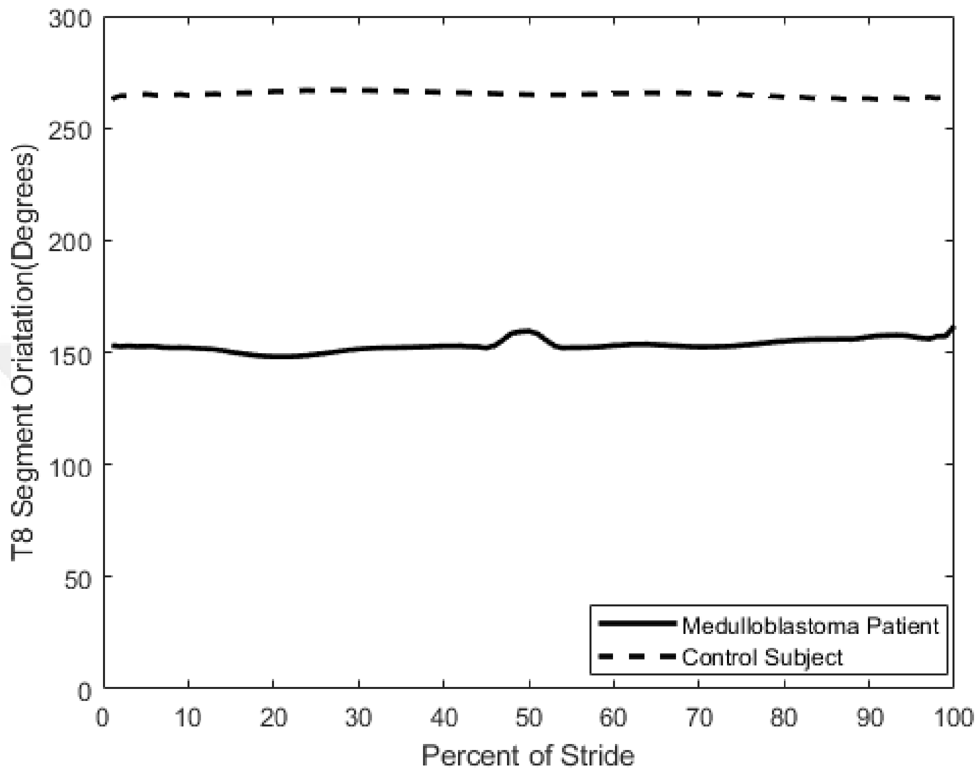
Medulloblastoma Patient was performing the same test as control subject in controlled environment with the assist of the physiotherapist (Photo 2.4).

Photo 2.4 Medulloblastoma Patient Performing Single Leg (Left Leg) Assessment Test with Real-time Balance Biofeedback Device

3 RESULTS

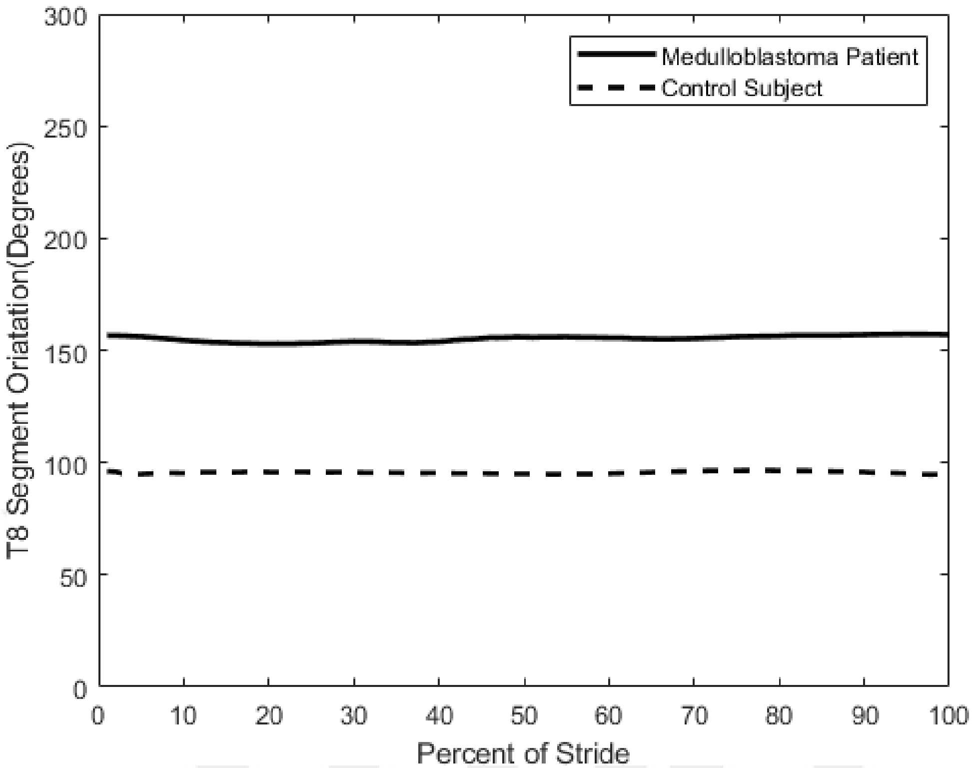
3.1 10 Meters Walking Data

3.1.1 Sternum (T8) orientation degrees in 10 meters walking test



Graph 3.1 Sternum (T8) IMU Orientation in Degrees without Real-time Balance Biofeedback

In Graph 3.1, Sternum orientation degree values were examined between Medulloblastoma Patient and Control Subject. Sternum degree pattern of the Medulloblastoma patient indicated that the subject had foot drop during the late-stance phase to improper and insufficient ankle joint dorsiflexion and knee joint flexion/extension. Also differences in degrees show that Medulloblastoma patient slouches more than normal range to maintain balance. Similar pattern was not obtained for the healthy control subject. Her sternum orientation pattern indicated that the participant performed the test while her posture was abnormally perpendicular and the center of gravity line approximated posterior.

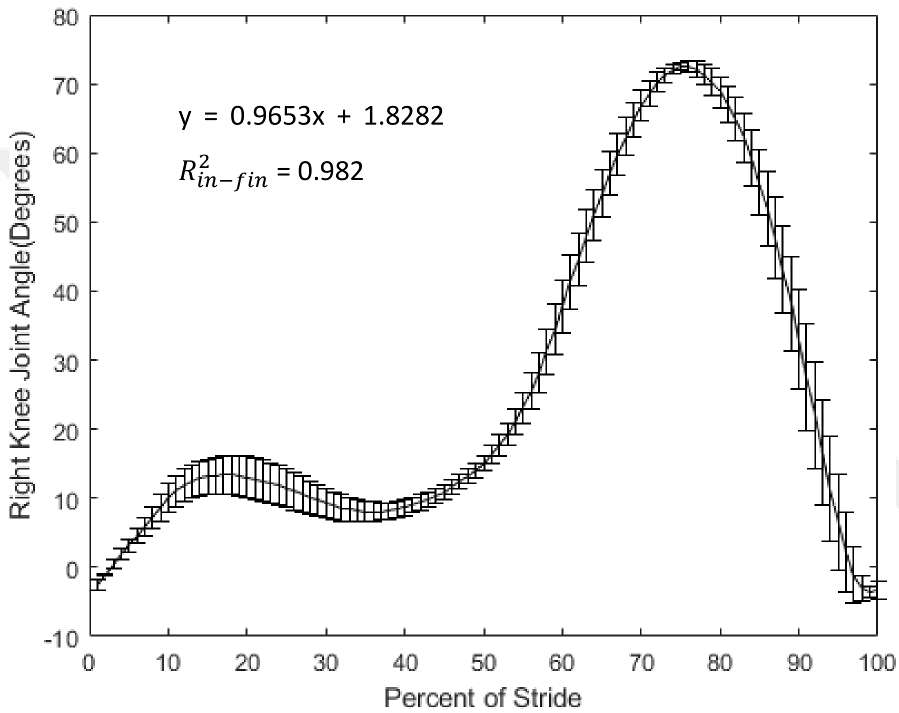


Graph 3.2 Sternum (T8) IMU Orientation in Degrees with Real-time Balance Biofeedback

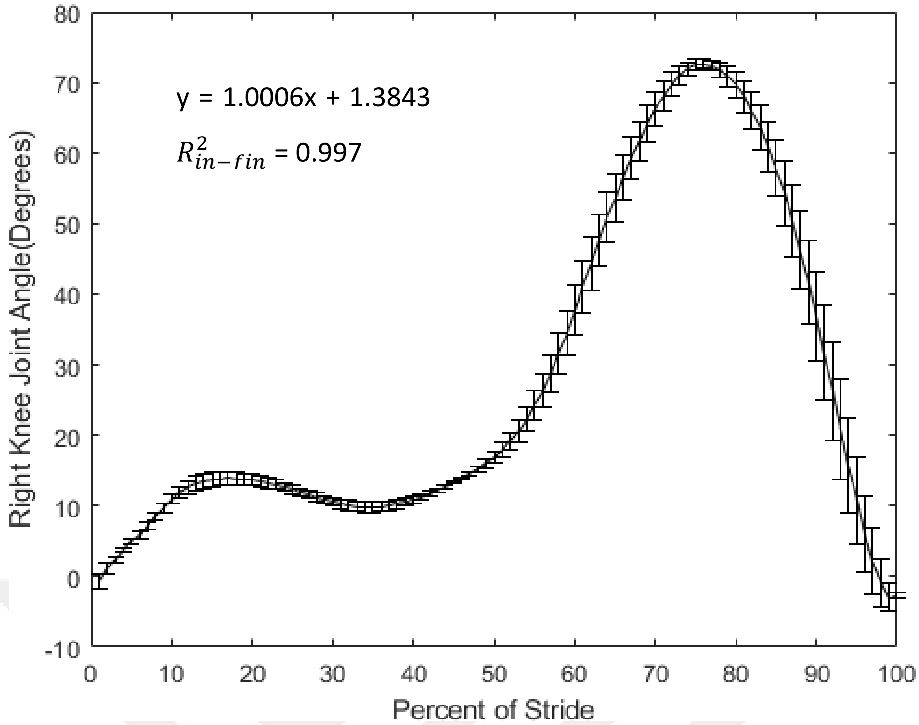
Sternum (T8) segment orientation degrees between Medulloblastoma Patient and Control Subject (Graph 3.2) indicates that Medulloblastoma patient's sternum orientation degrees normalized and patient is standing more straight when haptic biological feedback is given while 10 meters walking test. Also, there is not any peak values in T8 segment orientation degrees in patient.

3.1.2 Right knee joint angle in 10 meters walking

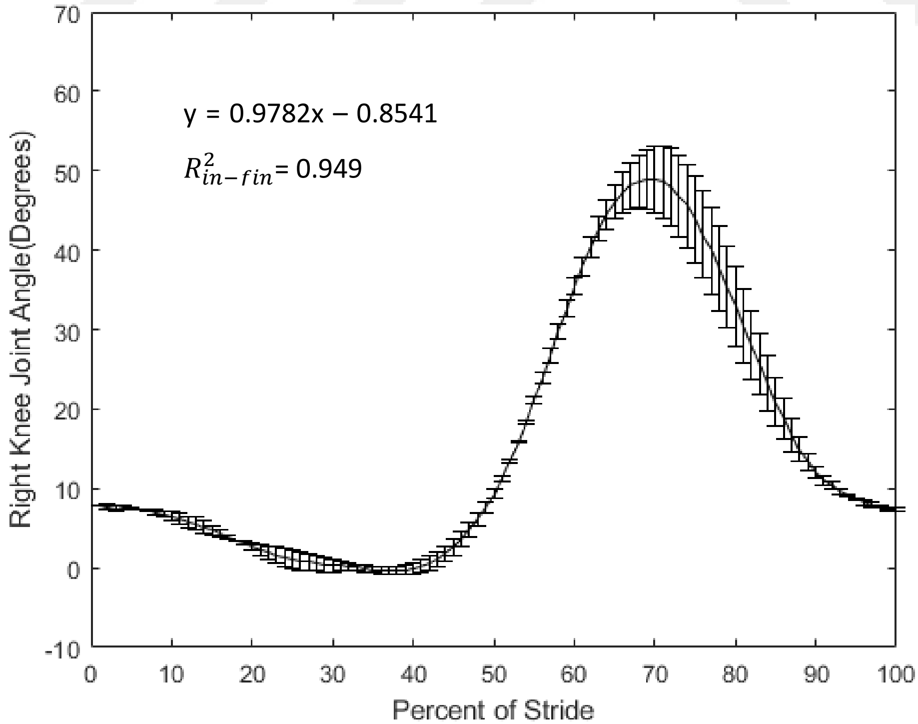
Control Subject's dominated knee joint angles with and without feedback graphs (Graph 3.3 and Graph 3.4) indicate that there is no significant difference between them in both stance and swing phase. However, when biofeedback was given, standard deviations are smaller especially in control subject's stance phase as it seen in Graph 3.3. This indicates more symmetry between every steps.



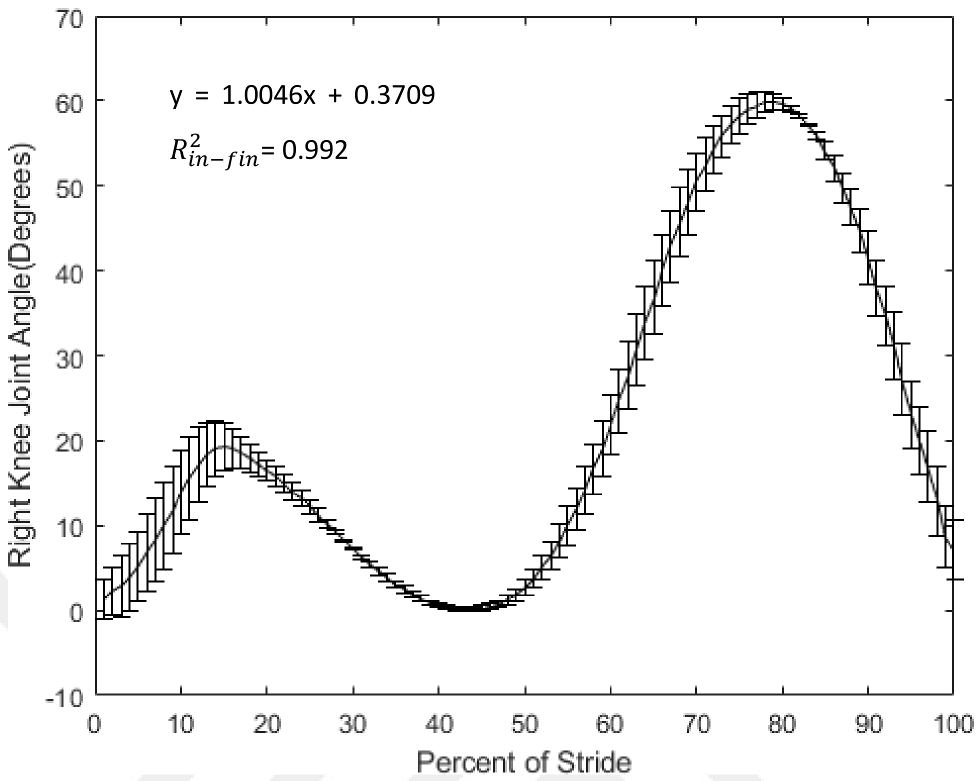
Graph 3.3 Average Right Knee Joint Angles in Degrees and Standard Deviation of Control Subject without Biofeedback



Graph 3.4 Average Right Knee Joint Angles in Degrees and Standard Deviation of Control Subject with Biofeedback



Graph 3.5 Average Right Knee Joint Angles in Degrees and Standard Deviation of Medulloblastoma Patient without Biofeedback

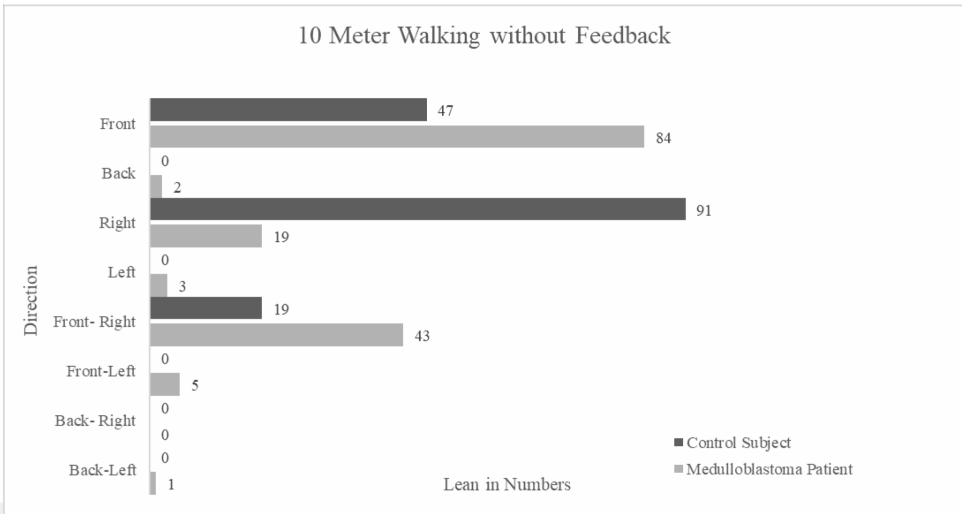


Graph 3.6 Average Right Knee Joint Angles in Degrees and Standard Deviation of Medulloblastoma Patient with Biofeedback

As it seen in Graph 3.5, right knee joint angle of Medulloblastoma Patient in stance phase has no peak like control subject has when there was not biofeedback given, this indicates Medulloblastoma Patient walks more rough than control subject and her knee flexion/extension movements peak range of motion is quite smaller than control subject while performing 10 meters walking without any tactile or visual biofeedback.

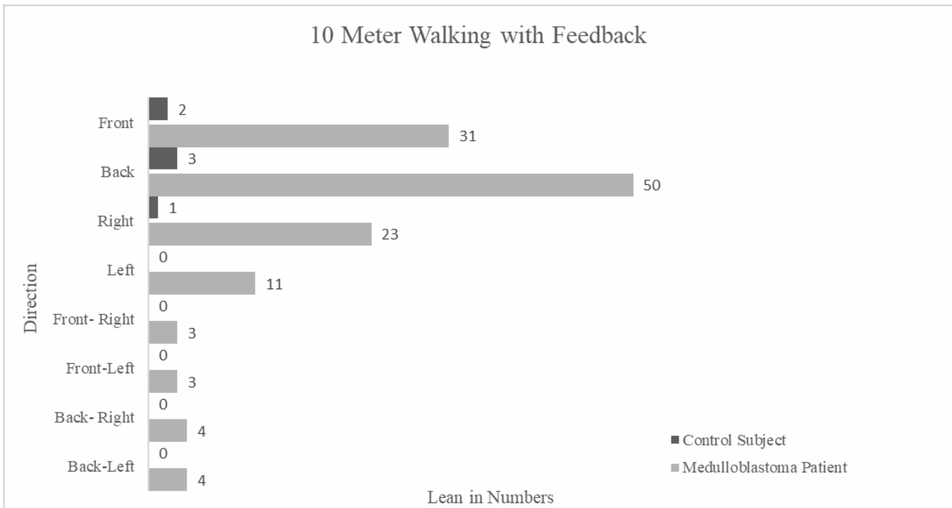
Medulloblastoma patient's dominated knee joint angle shows remarkable improvement in stance phase flexion/extension movement when patient was given a haptic biological feedback to maintain her balance while doing 10 meters walking test. There is also an improvement in medulloblastoma patient's peak value in swing phase when biological feedback is provided which can be seen in Graph 3.6.

3.1.3 Reports of wearable balance biofeedback device



Graph 3.7 Direction Report of Changing in Balance in Both Patient and Control Subject During 10 Meter Walking Without Feedback

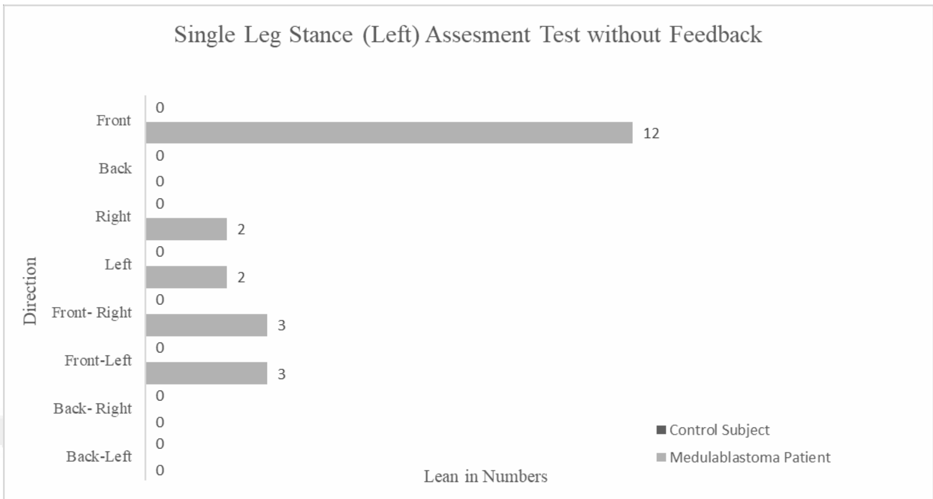
When Graph 3.7 and Graph 3.8 are compared, Medulloblastoma Patient without any biofeedback given leans on front direction the most while she also leans her right side and combination of both sides. On the other hand, Control Subject also leans front and back direction when there was no biofeedback. It is seen that they both control their balance when biofeedback was given in 10 meters walking test.



Graph 3.8 Direction Report of Changing in Balance in Both Patient and Control Subject During 10 Meter Walking with Feedback

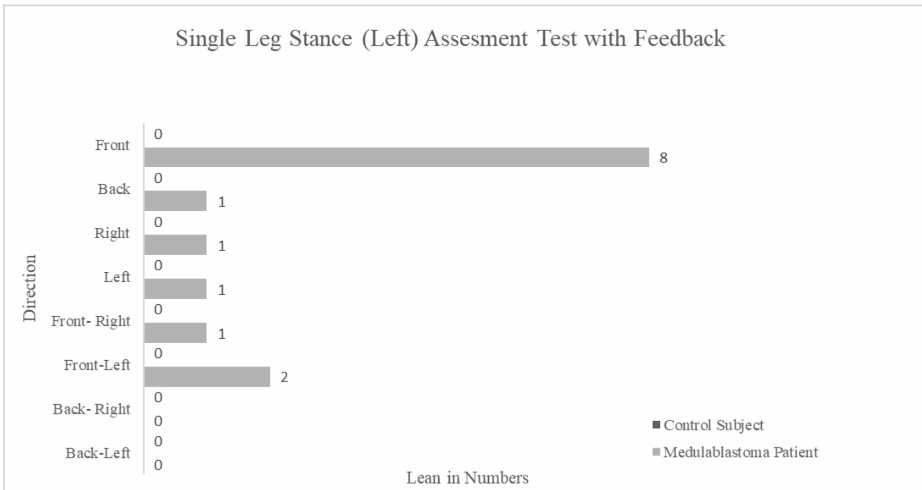
3.2 One Leg Stance Assessments Test

3.2.1 One leg (left) stance assessment test



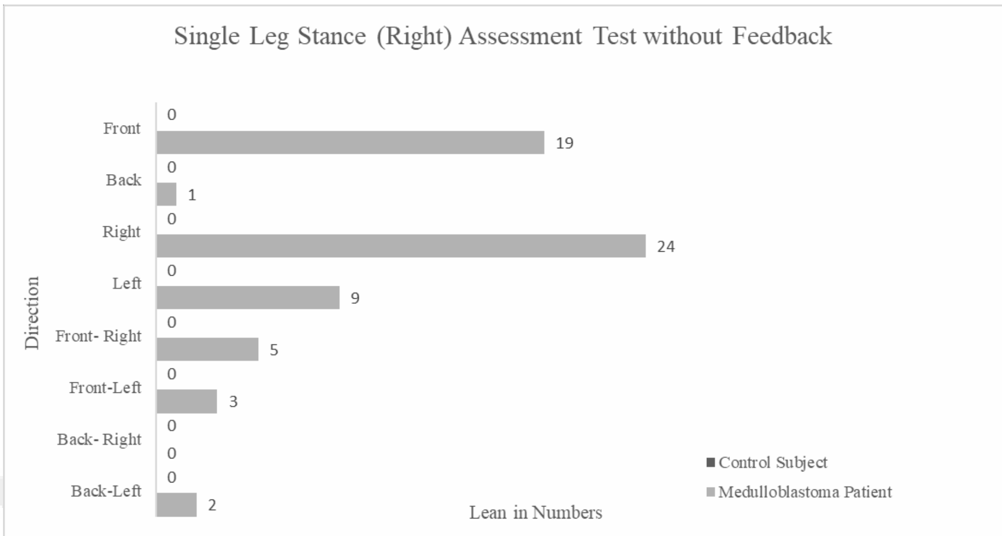
Graph 3.9 Direction Report of Changing in Balance in Both Patient and Control Subject During Single-Leg (Right Leg Up) Assessment Test Without Feedback

While Control Subject (CS) was very stable and her balance was almost perfect as it seems in Graph 3.9 and Graph 3.10, Medulloblastoma Patient (MP) leaned mostly her front direction in both cases. However, a significant improvement in all directions was observed when feedback was given to MP.



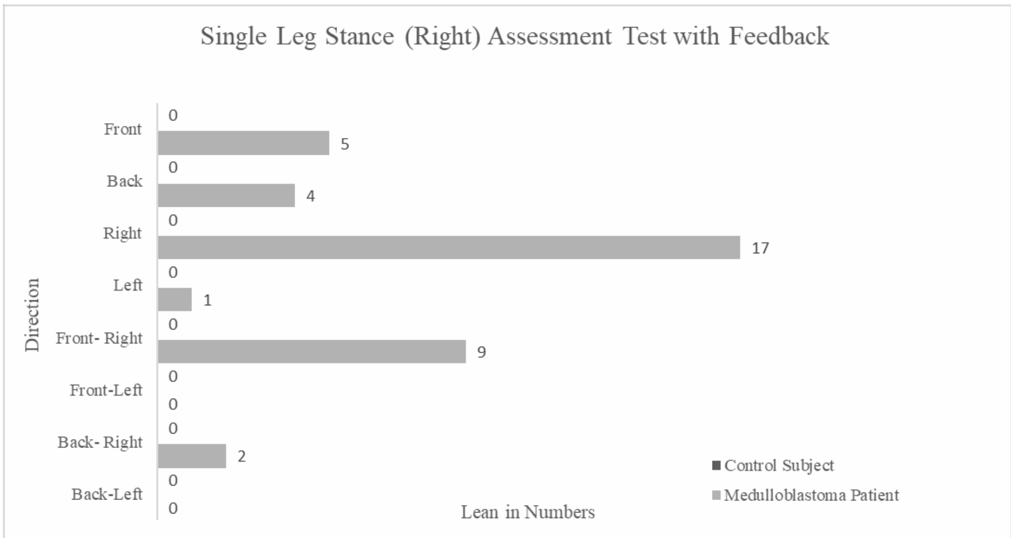
Graph 3.10 Direction Report of Changing in Balance in Both Patient and Control Subject During Single-Leg (Right Leg Up) Assessment Test with Feedback

3.2.2 One leg (right) stance assessment test



Graph 3.11 Direction Report of Changing in Balance in Both Patient and Control Subject During Single-Leg (Left Leg Up) Assessment Test Without Feedback

As it seen from Graph 3.11 and Graph 3.12, MP leaned mostly her right direction in both cases while CS was very stable and her balance was almost perfect like the same test with other leg. However, an improvement in all directions, especially in front direction, was observed when feedback was given to MP.



Graph 3.12 Direction Report of Changing in Balance in Both Patient and Control Subject During Single-Leg (Left Leg Up) Assessment Test With Feedbac

3.3 Statistical Analyses

IBM SPSS Statistics v21.0 was used to perform the statistical analyses. Normal distribution was confirmed with Shapiro-Wilk Test of Normality. A paired t-test was used to evaluate the effect of the real-time tactile biofeedback mechanism on patient's knee joint kinematics.

Paired t-test analysis revealed that the patient's knee joint range of motion was significantly similar throughout the data collection session when real-time tactile biofeedback was provided to the patient (61.9 degrees ± 3.4 SD vs. 54.8 degrees ± 1.7 SD; $t_{(0.05,29)} = 10.2$, $p<0.001$). Statistically, the effect of the sensor was not found to be statistically significant with the healthy control (71.9 degrees ± 2.2 SD vs. 72.8 degrees ± 0.9 SD; $t_{(0.05,29)} = -1.8$, $p=0.08$).

Pearson correlation coefficients were investigated (Graph 3.3, Graph 3.4, Graph 3.5, Graph 3.6) for each tasks and subjects between initial and final gait segments. . Pearson coefficient of the medulloblastoma patient ($r^2_{MP\ WO\ FB}$=0.94, $r^2_{MP\ W\ FB}$= 0.99) and healthy participant ($r^2_{CS\ WO\ FB}$=0.98, $r^2_{CS\ W\ FB}$= 0.99) of the knee joint angles were indicated perfect correlation and a high curve symmetry for both subjects for each task was obtained.

4 DISCUSSION

The aim of this study was to develop a novel tactile biofeedback mechanism and to investigate the influence of tactile biofeedback on achieving and maintaining balance during ambulation. Recent studies converge that biofeedback is a useful tool for maintaining participation, motivation and global motor function domains of the participant (34,35). Our findings agree for influence of tactile input on achieving balanced ambulation (36) and on minimizing sway (37). The influence of tactile biofeedback has been demonstrated in children and adults (38,39).

Physical activity adaptation, which is the optimal motor control response of the body to deliver performance, is a complicated process that involves various physiological systems, thus tactile biofeedback was used to optimize walking and single leg stance tests through sensory and proprioceptive guidance. The findings of this study indicated that physical activity adaptation should be supported continuously for maintaining the postural control and balance to sustain optimal energy consumption and kinematic parameters (40).

According to MPU 9250 located in sternum, the axial body as a simple pendulum, sternum being the bob, the amount that the pendulum bob is displaced to the left, right, back or front or the combination of two axes. When biological feedback is provided, our test results show that the range of the pendulum movement is much smaller, therefore participants are much more in the normal range which was 5 degrees in single-leg stance assessment test and 10 degrees in 10 minutes walking in every direction (this information was given by the physical therapist herself according to patient’s balance range). As one can easily see that, control subject has not lean on any direction while performing one-leg stance assessment test. While medulloblastoma patient’s pendulum movement is always higher than the thresholds but still got improved by the biofeedback. Last but not least, as it seen in Graph 3.1, there was a peak in medulloblastoma patient’s sternum segment’s orientation angle because of patient falling foot while performing 10 meters walking test. However, when biological feedback is applied, there was a smooth and much better pattern is observed. When it comes to control subject, she was walking really straight while performing 10 meter walking without feedback exercise which can be seen in the Graph 3.2, the degree of her sternum is much higher than it should be in without feedback session. Differences in degrees can be easily seen between graph 3.1 and graph 3.2, control subject walked more carefully when haptic biofeedback is given.

Heart Rate of both medulloblastoma patient and control subject had increased after the session. However, because of the fatique tumor gives the medulloblastoma patient, her heart rate was going up more than control subject (33).

5 CONCLUSION

The ability to provide stability and balance is critical for the neurological and orthopedic rehabilitation, because the ultimate goal is to achieve functional independence during ambulation. Pediatric brain tumor patients experience a decrease in their quality of life after treatment due to their psychomotor problems and altered motor functions. Pediatric patients who suffer from brain tumors encounter difficulties in weakness, coordination and balance problems while performing daily living activities, and these are not only affect their motivation, but also these are the factors that limit their motor abilities which are of great importance in daily living activities and quality of life (2,3). The absence of gait symmetry, which is the ratio of kinetic and kinematic parameters between right and left extremities, results in differences in muscle contraction, balance and biomechanical parameters during mobilization, and therefore causues possible injuries. Accurate knowledge of static and dynamic proprioception is essential to maintain proper body weight and sustain normal ambulation (4). Postural control and balance, which require complex synchronization of muscles and ligaments, is essential for optimal mobilization. Balance disorders cause irregular heart rate and center of mass pattern therefore, together with fatigue and therefore depression, is one of the main factors in the early termination of the performed exercise.

Biofeedback is a method of providing real-time feedback to the patient using auditory, visual, and tactile stimulus. Additionally, physician and/or physiotherapist can utilize biofeedback mechanisms in order to regulate the gait pattern, correct balance/posture, and thus create personalized physiotherapy rehabilitation programs for the patients while regulating the physiological, kinetic and kinematic variables.

6 FUTURE WORK

In this work, it is studied that biofeedback may be used to support physiotherapy rehabilitation process of a patient with brain tumor (medulloblastoma) as a pilot study. Scheduling this process as a recurring event in patients' rehabilitation program will make the patient get used to process easier and make it more efficient for future studies.

Further studies would make it possible to implement this pilot study to rehabilitation programs in most proper way with physiotherapists and medical doctors. Even if the method is studied with medulloblastoma patients in this work, it would be evaluated as a base for further studies for different kind of neurodegenerative diseases.

In the study, it is observed that with a single pilot run, there is a significant improvement, and if the process scheduled as recurring event with certain periods, taking learning factor of patients into account, it is possible to see further improvement in patients' proprioception.

To not to cause any interaction problem, wearable balance biofeedback device is designed with cable connection, but in further works (12 patients and 12 control subjects) the new version of device will be designed with wireless connection.

Other areas, in which wearable balance biofeedback device would be used as biological feedback, will be taken as research topics and would be evaluated as future works .

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APPENDIX

Evrak Tarih ve Sayısı: 10/05/2019-8251

T.C.
BEZMİALEM VAKIF ÜNİVERSİTESİ REKTÖRLÜĞÜ
Girişimsel Olmayan Araştırmalar Etik Kurulu

Sayı : 54022451-050.05.04-
Konu : Etik Kurul Kararı

Sayın Doç.Dr. Fatma Betül ÇAKIR

30.04.2019 tarihinde yapılan Girişimsel Olmayan Araştırmalar Etik Kurulu toplantısında "Beyin Tümörlü Çocuklardaki Denge Kaybının Kinematik Olarak İncelenmesi ve Eş Zamanlı Taktil Biyolojik Geri Bildirim Sistemi ile Denge Kontrolünün Değerlendirilmesi" başlıklı başvurunuz değerlendirilmiş olup karar yazısı ektedir.

Bilgilerinize.

e-imzalıdır
Prof.Dr. İsmail MERAL
Başkan

10/05/2019 Sek. V. Bilgihan BAŞTUĞ

Adres:Bezmiâlem Vakıf Üniversitesi Adnan Menderes Bulvarı (Vatan Caddesi) Fatih / Istanbul
Telefon:0 (212) 523 22 88 Faks0 (212) 533 23 26
e-Posta:info@bezmialem.edu.tr Elektronik Ağ:www.bezmialem.edu.tr

Bilgi için: Bilgihan BAŞTUĞ (Elif Gamze POLAT Vekaletiyle)
Unvanı: Sekreter

BEZMİALEM VAKIF ÜNİVERSİTESİ GİRİŞİMSEL OLMAYAN KLİNİK ARAŞTIRMALAR ETİK KURULU (2011-KAEK-42)
KARAR FORMU

ARAŞTIRMANIN AÇIK ADI	Beyin Tümörlü Çocuklardaki Denge Kaybının Kinematik Olarak İncelenmesi ve Eş Zamanlı Taktil Biyolojik Geri Bildirim Sistemi ile Denge Kontrolünün Değerlendirilmesi

30.04.2019

ETİK KURUL BİLGİLERİ	ETİK KURULUN ADI	Bezmialem Vakıf Üniversitesi Girişimsel Olmayan Araştırmalar Etik Kurulu
	AÇIK ADRESİ:	Adnan Menderes Bulvarı Vatan Caddesi 34093 Fatih/İstanbul
	TELEFON	(0212) 523 22 88 - 3238
	FAKS	(0212) 533 23 26
	E-POSTA	egaslan@bezmialem.edu.tr

BAŞVURU BİLGİLERİ	KOORDİNATÖR/SORUMLU ARAŞTIRMACI UNVANI/ADI/SOYADI	Doç. Dr. Fatma Betül ÇAKIR			
	KOORDİNATÖR/SORUMLU ARAŞTIRMACININ UZMANLIK ALANI	Pediatrik hematoloji/onkoloji			
	ARAŞTIRMAYA KATILAN MERKEZLER	TEK MERKEZ ☒	ÇOK MERKEZLİ ☐	ULUSAL ☐	ULUSLARARASI ☐

DEĞERLENDİRİLEN BELGELER	**Belge Adı**	**Tarihi**	**Versiyon Numarası**	
	ARAŞTIRMA PROTOKOLÜ	-	-	Gerekli Değil ☐ Var ☒
	BİLGİLENDİRİLMİŞ GÖNÜLLÜ OLUR FORMU	-	-	Gerekli Değil ☐ Var ☒
KARAR BİLGİLERİ	**Karar No: 09/155**	**Tarih: 30.04.2019**		
	Yürütücülüğünü Doç. Dr. Fatma Betül ÇAKIR' ın yaptığı "Beyin Tümörlü Çocuklardaki Denge Kaybının Kinematik Olarak İncelenmesi ve Eş Zamanlı Taktil Biyolojik Geri Bildirim Sistemi ile Denge Kontrolünün Değerlendirilmesi " Girişimsel Olmayan Araştırmalar Etik Kurulu tarafından değerlendirilmiş ve etik açıdan uygun bulunmuştur.			

Sayfa **1 / 2**

Etik Kurul Başkanı
Prof. Dr. İsmail MERAL

BEZMİALEM VAKIF ÜNİVERSİTESİ GİRİŞİMSEL OLMAYAN KLİNİK ARAŞTIRMALAR ETİK KURULU (2011-KAEK-42)
KARAR FORMU

ARAŞTIRMANIN AÇIK ADI	Beyin Tümörlü Çocuklardaki Denge Kaybının Kinematik Olarak İncelenmesi ve Eş Zamanlı Taktil Biyolojik Geri Bildirim Sistemi ile Denge Kontrolünün Değerlendirilmesi

BEZMİALEM VAKIF ÜNİVERSİTESİ GİRİŞİMSEL OLMAYAN ARAŞTIRMALAR ETİK KURULU	
ETİK KURULUN ÇALIŞMA ESASI	İlaç ve Biyolojik Ürünlerin Klinik Araştırmaları Hakkında Yönetmelik, İyi Klinik Uygulamaları Kılavuzu
BAŞKANIN UNVANI / ADI / SOYADI:	Prof. Dr. İsmail MERAL

Unvanı/Adı/Soyadı	Uzmanlık Alanı	Kurumu	Araştırma ile ilişki		Katılım *		İmza
Prof. Dr. İsmail MERAL	Fizyoloji	Bezmialem Vakıf Üniversitesi Tıp Fakültesi	E ☐	H ☒	E ☒	H ☐	
Prof. Dr. Ömer SOYSAL	Göğüs Cerrahisi	Bezmialem Vakıf Üniversitesi Tıp Fakültesi	E ☐	H ☒	E ☒	H ☐	
Prof. Dr. Nuran YILDIRIM	Tıp Tarihi ve Etik	Bezmialem Vakıf Üniversitesi	E ☐	H ☒	E ☒	H ☐	
Prof. Dr. Türkinaz AŞTI	Hemşirelik Bölümü	Bezmialem Vakıf Üniversitesi Sağlık Bilimleri Fakültesi	E ☐	H ☒	E ☒	H ☐	
Prof. Dr. Semra ÖZÇELİK	Tıp Eğitimi ve Bilişimi	Bezmialem Vakıf Üniversitesi Tıp Fakültesi	E ☐	H ☒	E ☐	H ☒	Katılmadı
Prof. Dr. Teoman AYDIN	Fiziksel Tıp ve Rehabilitasyon	Bezmialem Vakıf Üniversitesi Tıp Fakültesi	E ☐	H ☒	E ☒	H ☐	
Doç. Dr. Fahri AKBAŞ	Tıbbi Biyoloji	Bezmialem Vakıf Üniversitesi Tıp Fakültesi	E ☐	H ☒	E ☒	H ☐	
Doç. Dr. Binnur AYDOĞAN TEMEL	Eczacılık	Bezmialem Vakıf Üniversitesi Eczacılık Fakültesi	E ☐	H ☒	E ☒	H ☐	
Doç. Dr. Aclan ÖZDER	Aile Hekimliği	Bezmialem Vakıf Üniversitesi Tıp Fakültesi	E ☐	H ☒	E ☐	H ☒	Katılmadı
Doç. Dr. Nazmiye DÖNMEZ	Restoratif Diş Tedavisi	Bezmialem Vakıf Üniversitesi Diş Hekimliği Fakültesi	E ☐	H ☒	E ☒	H ☐	
Doç. Dr. Nur BÜYÜKPINARBAŞILI	Tıbbi Patoloji	Bezmialem Vakıf Üniversitesi Tıp Fakültesi	E ☐	H ☒	E ☐	H ☒	Katılmadı
Av. Mustafa Fırat ALKAYA	Hukuk	Bezmialem Vakıf Üniversitesi	E ☐	H ☒	E ☒	H ☐	
Eda BAYRAKTAR	Sivil Üye	Bezmialem Vakıf Üniversitesi	E ☐	H ☒	E ☐	H ☒	Katılmadı

* :Toplantıda Bulunma **Karar:** ☒ Onaylandı ☐ Reddedildi

Sayfa **2 / 2**

Etik Kurul Başkanı
Prof. Dr. İsmail MERAL

RESUME

Personal Information

Name	Begüm	**Surname**	Yalçın
Birth Place	Ankara	**Birth Day**	06/03/1992
Nationality	T.C	**Phone Number**	+902165004389
E-mail	begum.yalcin@acibadem.edu.tr ; begum.acibadem@gmail.com		

Education

	Institution	Graduation Year
Undergraduate	Yeditepe University	2016
High School	Çankaya Milli Piyango Anatolian High School	2010

Experience

Position	Organization	Duration (Year – Year)
1. Research Assistant	Acibadem Mehmet Ali Aydinlar University	2018-Present

Language	Reading	Speaking	Writing
English	Very Good	Very Good	Very Good

Foreign Language Examination Grade									
KPDS	ÜDS	IELTS	TOEFL	TOEFL IBT	TOEFL CBT	CAE	CPE	YÖKDİL	YDS
				85					83.75

KPDS: Kamu Personeli Yabancı Dil Sınavı; ÜDS: Üniversitelerarası Kurul Yabancı Dil Sınavı; IELTS: International English Language Testing System; TOEFL IBT: Test of English as a Foreign Language-Internet-Based Test TOEFL PBT: Test of English as a Foreign, YDS: Yabancı Dil Seviye Tespit Sınavı

Language-Paper-Based Test; TOEFL CBT: Test of English as a Foreign Language-Computer-Based Test; FCE: First Certificate in English;

CAE: Certificate in Advanced English; CPE: Certificate of Proficiency in English

	Quantitative	Equally Weighted	Verbal
ALES Note	74.27202	66.99092	55.50135

Computer Skills

Program	Ability to use
Microsoft Office Programs	Good
Matlab	Good
Phyton	Good
C+	Good