DEVELOPMENT OF SEATING PRESSURE ULCER PREVENTION TRAINING SYSTEM FOR INDIVIDUAL WITH SPINAL CORD INJURY

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ABSTRACT

Pressure ulcer is a serious problem and complication for spinal cord injury (SCI) patients. There are various methods to prevent pressure ulcer which are good quality of cushion and perform pressure relief activity. This study aims to develop a device that can give alert to patients especially SCI to perform pressure relief activity such as push up. Patients need to have the capability and strength at upper body to perform this activity. The design consists of two elements to make the system successful which are sensor and control system. Light dependent resistor (LDR) was used as sensing element to trigger the control system that consists of buzzer and timer to alert the patients. Seven SCI subjects were involved to get the feedback regarding design specification and overall system application. Result from subject evaluation, device successfully alert patients to perform pressure relief activity after 15 minute. With pressure alert system, this device can help patient to cultivate pressure relief activity which can be an effective way to prevent pressure ulcer.

Keyword: Spinal Cord Injury (SCI), Pressure relief activity, Light dependent resistor (LDR), control system.

ABSTRAK

Ulser akibat tekanan merupakan masalah yang serius dan komplikasi kepada pesakit yang mengalami kecederaan tulang belakang.Terdapat pelbagai cara untuk merawat tekanan ulser ini iaitu kusyen yang berkualiti tinggi dan juga melakukan aktiviti mengurangkan tekanan. Kajian ini nensasarkan untuk memghasilkan peralatan yang boleh memberi peringatan kepada pesakit tulang belakang untuk melakukan aktiviti tersebut. Pesakit hendaklah mempunyai kekuatan pada bahagian atas badan untuk melakukannya. Rekaan peralatan ini mempunyai dua element iaitu system pengesan dan kawalan.*LDR* digunakan sebagai alat pengesan yang bertindak balas dengan sistem kawalan yang mempunyai pembunyi isyarat dan juga mempunyai pengukur masa untuk memberi peringatan kepada pesakit. Tujuh pesakit tulang belakang telah terlibat dalam memberi maklumbalas berkaitan dengan spesifikasi rekaan dan penggunaan sistem secara menyeluruh. Keputusan daripada penilaian kepada pesakit,peralatan berjaya memberi peringatan untuk melakukan aktiviti mengurangkan tekanaan selepas 15 minit. Dengan sistem peringatan ini, peralatan dapat membantu untuk memupuk pesakit melakukan aktiviti mengurangkan tekanan yang menjadi salah satu aktiviti yang berkesan bagi mengelakkan tekanan ulser.

Kata kunci: Tulang belakang, aktiviti mengurangkan tekanan, LDR, sistem kawalan

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LIST OF SYMBOL AND ABBREVIATIONS

AT	Assistive Technology
DC	Direct Current
EEM	Electronic Exercise Monitor
IT	Ischial Tuberosities
LCD	Liquid Crystal Display
LDR	Light Dependent Resistor
LED	Light Emitting Diode
SCI	Spinal Cord Injury
US	United States

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1.0 INTRODUCTION

1.1 BACKGROUND STUDY

1.1.1 SPINAL CORD INJURY (SCI)

Spinal cord injury may occur due to the damage of spinal cord because of trauma such as motor vehicle accident, violence or fall, loss of normal blood supply, or compression from tumor and infection. In the United States (US) it was estimated that around 200,000 people suffering from spinal cord injury. From the data obtained from National Spinal Cord Injury Association, most injuries occurred from a traumatic event (Living with spinal cord injury, 2011).There have two categories to describe the injury of spinal cord which are complete or incomplete. Complete spinal cord injury means that total loss of sensation and muscle function in the body below the level of injury (figure 1.1: level of injury). On the other hand, incomplete spinal cord injury means some remaining function below the level of injury. The injury occurs at upper of spinal cord can cause the quadriplegia paralysis of both arms and legs. While the injury lower of spinal cord can causes paraplegia paralysis of both legs only. Quality of life of individual with spinal cord injury seriously affected because of limitation of all activities of daily living. They need to use assistive technology (AT) to reinforce the daily activities. Wheelchair is the AT used by the people with SCI. Wheelchair can assist them to enhance the function, improve independence, and successfully enjoying their life (S.Chaves, L.Boninger, Cooper, G.Fitzgerald, B.Grau, & A.Cooper, 2004).

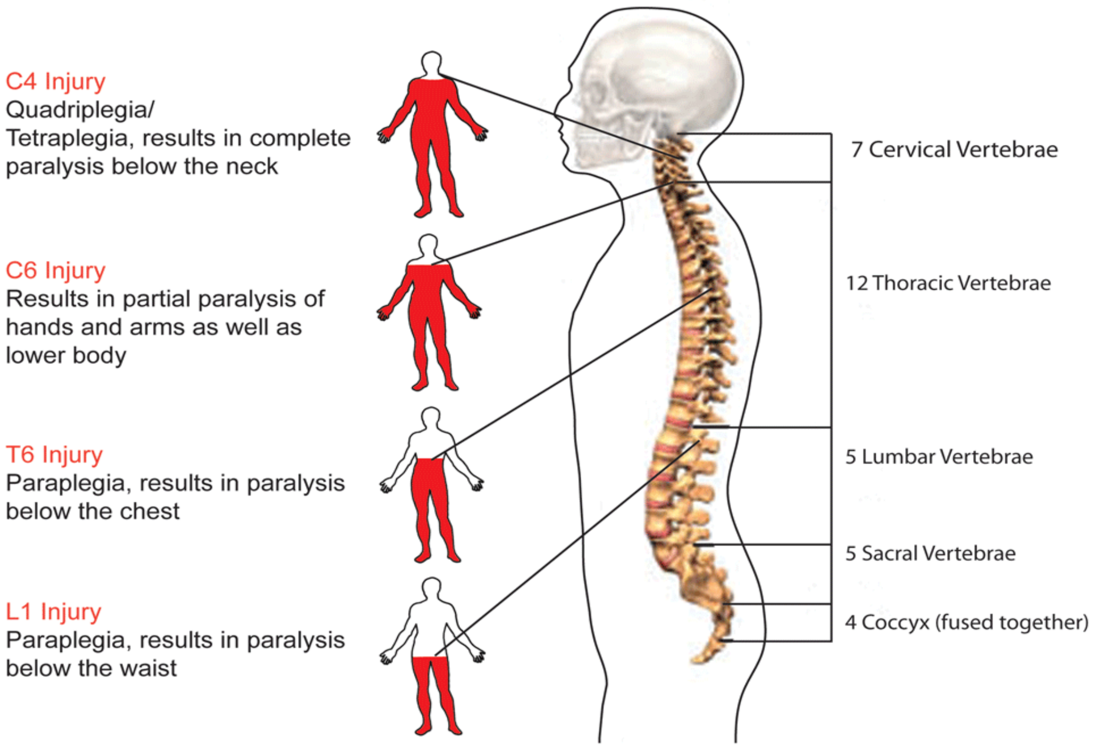

Figure 0-1: Level of SCI injury. Adapted from what is Spinal Cord Injury, www.spinalinjures.ie

1.1.2 WHEELCHAIR TECHNOLOGY

Wheelchair can be categorized as orthoses, since it is capable to provide spinal stabilization and replace the weak trunk musculature during static sitting and doing some activities (D.Hastings, Roger Fanucchi, & P.Burns,2003). Nowadays, a lot of companies contribute to design the best wheelchair especially for SCI subject. In the market, there are generally two types of wheelchairs which are manual or powered (figure 1.2: Example of wheelchair) (Morita, K, K, & T, 2012). A few aspects need to be highlighted during choosing the suitable wheelchair for the user. The first element that needs to be considered is environment, where the wheelchair is mostly used by the user for a long term. The type of wheel selected should be based on the usage. If the wheelchair is frequently used for indoor, the tyres should be slimmer to reduce the friction, while for outdoor usage the frame should be tough and the tyres should be thicker with better grip. Second element is the usage of the wheelchair use such as sport, work or leisure. Third element that need to be considered is the wheelchair controller, on how their capability to control the whole system of wheelchair or need an assistant to control it. Last element is the storage ability and flexibility of the wheelchair to be used for transportation (Bromley & Rose, 2006). The entire elements stated above, need to be considered when choosing a best and suitable wheelchair.

Figure 0-1: Example of powered wheelchair with cushion. Adapted from "The hammock effect of wheelchair cushion cover: persistent redness over the ischial tuberosities in subject with spinal cord injury-a case report" by Tomoyuki Morita, Tujimura K, Matsuda K, Yamada T,November 2012.

Other important aspects that need to be considered are the material and design of the cushion, since the SCI is a wheelchair-bounded subject. Various materials can be used in designing the seat cushion such as water, foam, gel, air and viscoelastic. The criteria of the cushion are important to make sure the correct position, stability, prevention of the ulcer, comfortable and decrease friction. Most cushions that are available in the market were designed to cater for a variety of the general subject and not specific to SCI subjects only (M.W, I.C, J.B, & J.C, 1980).

Some of the cushion comes with modification of the structure of the cushion's surface. They modified with additional support to relief the body weight and reduce the load especially at Ischialtuberosities and trochanters area. According to Mark et al studies, they have designed cushion with additional support to the buttock area. Furthermore, with proper support it can also help to increase the stability during sitting.

By increasing the back saddle area, added weight bearing surface was achieved with support at thighs and posterior pelvis. These supports were act as a cantilever, lifting the body weight and decrease the load at IT and trochanters (figure 1.3: design schematic) (Mark J., Robert, Dale L., Martin, Mark, & Joseph, 1996). Some cushion also comes with the shape that resembles to fit of a buttock area and uses comfortable and soft material at high level pressure area.

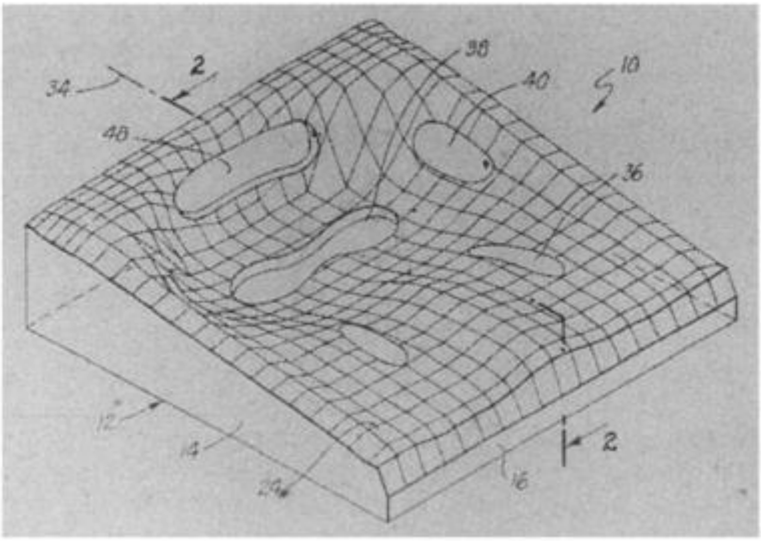

Figure 0-2: The schematic of cushion design with additional support to relief the pressure ulcer and enhance the stability. Adapted from "A wheelchair cushion designed to redistributes sites of sitting pressure", by Mark J. Rosenthal, Robert M.Felton, Dale L. Hileman, Martin Lee,Mark Friedman, Joseph H. Navach, January 1996,*Arch Phys Med Rehab II, 77.*

From the research, they have found that wheelchair may contribute the pressure ulcer because of the effect from the spinal alignment. The spinal alignment caused the seating interface pressure (Terry, MPhil, Arthur, & Y.L, 1996). On the other hand, selecting wrong cushion material can also contribute to the pressure ulcer. The good quality of cushion is strongly believed to help distribute the load around buttock and wheelchair (Mark J., Robert, Dale L., Martin, Mark, & Joseph, 1996).

1.1.3 PRESSURE ULCER

In the US, around 2.5 million pressure ulcers subjects are being treated each year (Madhuri, Sudeep, & Paula, 2006) .Individual with spinal cord injury (SCI) always suffer from poor skin conditions due to prolonged seating problem such as pressure ulcer. The pressure ulcer is the serious problem and complication for SCI subject (Mary Ann, Robert, Dalton, Keast, B.Mortenson, & Jo-Anne, 2009).It's happened because they spent most of their time in a day by sitting on wheelchair with no sense of pressure to initiate body-lifting. Around 5 and 10 % of the SCI subject will face the problem with pressure ulcer every year (R., C., J., & Guise, 2001). There are a few factors that contribute the pressure ulcer such as lack of sensation and immobility (Madhuri, Sudeep, & Paula, 2006). Some of the researcher listed out that the pressure ulcer area affected by the posture of the subject during sitting on the wheelchair, the position of the seat and the pressure of air cushions. It was also identified that around 60.3% of the pressure was distributed during sitting over the ischial tuberosities (IT) and sacrococcygeal region because of the poor sitting posture (figure 1.4) (Terry, MPhil, Arthur, & Y.L, 1996). Pressure ulcer occurs over the sacrum, greater trochanter, ischial tuberosity, malleolus, heel, fibular head and scapula (Jonathan, Karen, Darryl, Kevin, & Sherry, 1995).Theoretically, our body tissue can be tolerate with high pressure for short time, but for prolonged duration our blood supply and lymph drainage cannot be functioning well, tissue hypoxia appears and skin temperature increases (Mark J., Robert, Dale L., Martin, Mark, & Joseph, 1996). Besides that, pressure can also occur due to the combination of the pressure with shear force or friction (Mary Ann, Robert, Dalton, Keast, B.Mortenson, & Jo-Anne, 2009).

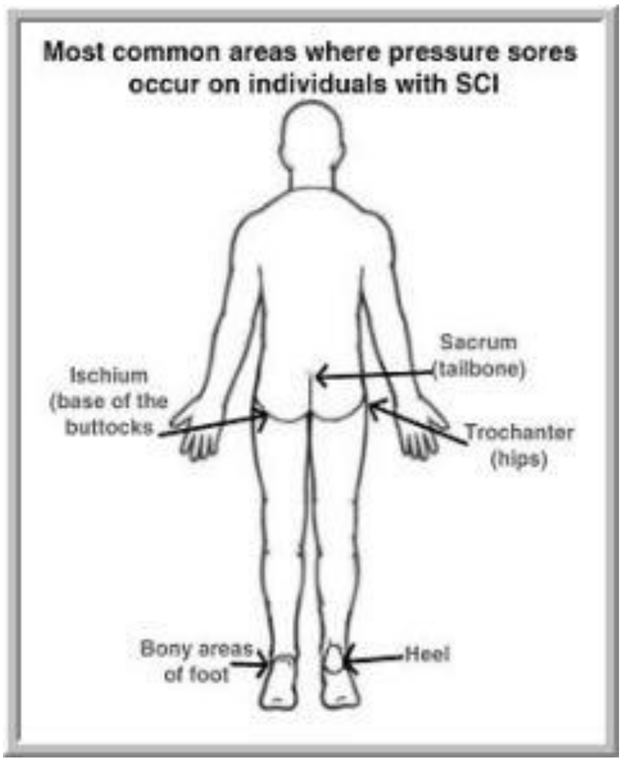

Figure 0-1: The area of pressure ulcer. Adapted from “How a pressure sore develops” by United Spinal Association, askus.unitedspinal.org.

Pressure ulcer can be classified by staging the degree of tissue damage. In 1989, the National Pressure Ulcer Advisory Panel have been developed the staging system. It consists of four (4) stages that range in severity from stage 1 (intact skin) until stage 4 (full thickness skin loss) as show in table 1.1 (Mary Ann, Robert, Dalton, Keast, B.Mortenson, & Jo-Anne, 2009).

Table 0-1: Stages of Pressure Ulcer

Stage	Descriptions
Suspected deep tissue injury	Purple or maroon localized area of discolored intact skin or blood-filled blister caused by damage underlying soft tissue from pressure and/or shear force. The area may be preceded by tissue that is firm, mushy, boggy, warmer, or cooler compared with adjacent tissue.
Stage 1	Intact skin with nonblanchable redness of localized area, usually over a bony prominence. Darkly pigmented skin may not have visible blanching; its color may differ from the surrounding area.
Stage 2	Partial thickness loss of dermis presenting as a shallow open ulcer with a red/pink wound bed, without slough. May also present as an intact or open/ruptured serum-filled blister.
Stage 3	Full-thickness tissue loss. Subcutaneous fat may be visible, but bone, tendon, or muscles are not exposed. Slough may be present but does not obscure the depth of tissue loss. May include undermining and tunneling.
Stage 4	Full-thickness tissue loss with exposed bone, tendon, or muscle. Slough or eschar may be present in some parts of the wound bed. Often includes undermining and tunneling.
Unstageable	Full-thickness tissue loss in which the base of ulcer is covered by slough (yellow, tan, gray, green, or brown) and/or eschar (tan, brown, or black) in the wound bed.

Note. Stages of pressure ulcer. Reprinted from “Pressure Ulcers: Preventation and Management” ,by Jonathan M.Evans, Karen L. Andrews, Darryl S.Chutka, Kevin C. Fleming, Sherry L.Garness. (1995),*Mayo Clin Proc, 70.*

Development of the pressure ulcer not only serious but also the cost of treatment is high and life-long complication of SCI. In the US, the total cost to manage the full thickness (stage 4) of pressure ulcer can reach up to $ 70000 which is about RM 221,585. A variety of preventive methods have been approached may be less costly and very unpleasant. The preventive that always recommended that able to reduce the sitting pressure ulcer including pressure redistribution cushion and pressure relieves activities like push up and lean forward (Ayelet, Kopplin, & Gefen, 2013).

There will be able to reduce the mechanical stress, which is the main cause of the blood supply clot to the skin.

1.1.4 PREVENTIVE STRATEGY

Many researches and rehabilitation departments came out with many solutions to prevent the pressure ulcer. The most effective way to prevent the ulcer is the design of the cushion and the posture of the body during sitting on the wheelchair. There are few technologies that have already developed to measure the pressure ulcer. The high end technology may be irrelevant to the common low-income subjects. Thus, a prevention strategy is deemed more suitable. All around the world have been used the rehabilitation program as below:

i. Perform routine pressure relieve activities such as push up every 15-30 minutes- by placing the hand on wheelchair's armrest and pushing down to extend the elbow , lifting the buttock for a few minutes to relieve the load around the soft tissue.

ii. Use soft cushion on the wheelchair – help to get better distribution of load surrounding buttock and wheelchair (Ayelet, Kopplin, & Gefen, 2013).

The objective of this program is to reduce the load at tissue area as much as possible. Besides that, to sustain the thermodynamic microenvironment level such as temperature, moisture and humidity control in the skin and also to make sure no changes in skin mechanical properties.

For the individuals with paraplegia, the wheelchair push up is always counseled by rehab doctor because it is capable to relief the pressure ulcer (figure 1.5). But the subject should have strong upper body to lift off. For individuals with quadriplegia who are unable to lift off, they can do forward or side leans exercise (Jeffrey & T.Merbitz, 1986).

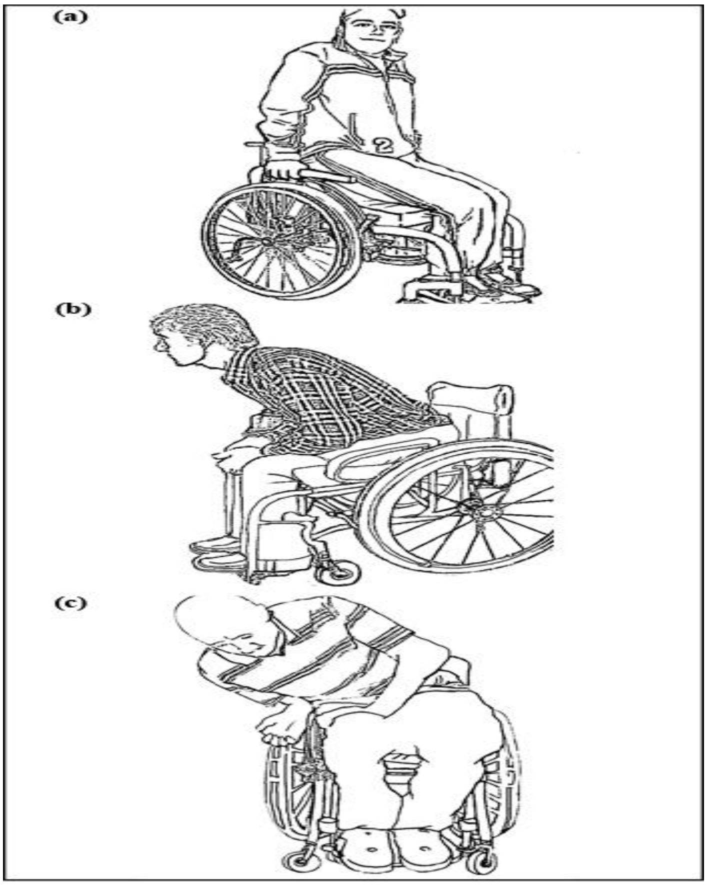

Figure 0-1: Pressure relieves activities. Adapted from "Assessing evidence supporting redistribution of pressure for pressure ulcer prevention: a review", by Stephen Sprigle, Sharon Sohenblum, 2011, JRRD, 48.

Unfortunately, there is no concrete evidence in how frequent and duration for push up and health authorities currently provide general guidelines. There is also no statistical evidence that push up can prevent the pressure ulcer. The panel for prediction and prevention of pressure ulcers in adults publishes the guidelines for prevention of the ulcers show in table 1.2 (Jonathan, Karen, Darryl, Kevin, & Sherry, 1995).

Table 0-1: Guidelines for Prevention of Pressure Ulcer

Mechanical loading and support surface guidelines

- For bed-bound persons
  - Reposition at least every 2 hours
  - Use pillows or foam wedges to keep bony prominences from direct contact
  - Use devices that totally relieve pressure on the heels
  - Avoid positioning directly on the trochanter
  - Elevate the head of the bed as little and as briefly as possible
  - Use lifting devices to move rather than drag persons during transfers and position changes
  - Place at-risk persons on a pressure-reducing mattress. Do *not* use doughnut-type devices*
- For persons in wheelchairs
  - Reposition at least every hour
  - Have patient shift weight every 15 minutes if able
  - Use pressure-reducing devices for seating surfaces. Do *not* use doughnut-type devices*
  - Consider postural alignment, distribution of weight, balance and stability, and pressure relief when positioning persons in chairs or wheelchairs
  - Use a written plan

Skin care and early treatment guidelines

- Inspect skin at least once a day
- Individualize bathing schedule; avoid hot water; use a mild cleansing agent
- Minimize environmental factors such as low humidity and cold air. Use moisturizers for dry skin
- Avoid massage over bony prominences
- Use proper positioning, transferring, and turning techniques
- Use lubricants to reduce friction injuries
- Institute a rehabilitation program
- Monitor and document interventions and outcomes

Note. Guidelines for prevention of pressure ulcer. Reprinted from "Pressure Ulcers: Preventation and Management", by Jonathan M.Evans, Karen L. Andrews, Darryl S.Chutka, Kevin C. Fleming, Sherry L.Garness. (1995),*Mayo Clin Proc, 70.*

Other factors that need to be focused on preventing the pressure are during cushion selection, training the subject with good hygiene, avoiding the friction and shears force and always perform pressure relief with appropriate time interval. Subjects should monitor the skin structure and perform frequent pressure relief for the rest of their life (Jeffrey & T.Merbitz, 1986).

On the other hand, there have a few treatments used to prevent the pressure ulcer. Since 1960, the electrical stimulation used to reduce the pressure ulcer. This system can help to increase the blood flow at sacral and gluteal areas. By increasing the blood flow, it is able to enhance the tissue viability and also prevent the pressure ulcer. In other word, this system can improve the tissue perfusion and reduce the edema formation to stimulate healing by improving oxygen delivery to tissue. Second treatment is laser, already used since 1970 as therapeutic device to heal the wound. Laser treatment act during the proliferative phase of wound healing to promote fibroblast activity and increase granulation tissue formation in non-healing, chronic wound. Lastly, the US/UVC treatment being used during chronic wound that act during inflammatory stage of wound healing (Mary Ann, Robert, Dalton, Keast, B.Mortenson, & Jo-Anne, 2009).

1.2 SIGNIFICANCE OF PROJECT

Pressure ulcer is skin lesions that are serious and anyone with SCI is facing the risk of developing pressure ulcer (Marylou, L.Garber, H.Bombardier, Durazo-Arizu, Goldstein, & Holmes, 2007).The pressure ulcer has been affected about 5-10 % of the SCI wheelchair user each year (R., C., J., & Guise, 2001).

Pressure measurement system is one of the technologies that available in the market that capable to monitor the pressure ulcer over buttock area. This system can only provide the result of the area that pressure ulcer may occur. There have a few other methods to prevent the pressure relief which is the material of the cushion, posture of the sitting on wheelchair and body lifting activities.

For an acute SCI subject, doing wheelchair push up is more relevant than buying the expensive cushion. However to train the subject to do the push up as routine may be difficult especially for subject who did not hospitalized so the rehab doctor may not able to monitor their progress by every day.

Development of the low cost pressure ulcer prevention system that capable of reminding and providing awareness to the subject used to train them to do body lifting exercise such as wheelchair push off as their routine of life. This project will be able to help the subject to remind them to do the push up and train as their habit for a rise of their life. This development are not be used as long term system, but as system that train the subject habit in handling the pressure ulcer. Once the subject can create the habit, they may leave the system and continue without alert system.

1.3 OBJECTIVE OF THE PROJECT

The objective of this project is to develop a system is that capable of alerting the subject to do the pressure relieving activities. This system is believed to help in the prevention on pressure ulcer, but longitudinal testing of subject behavior is beyond the scope of this project.

The system that consists of light dependant resistor (LDR) which is connected to timer and buzzer was designed to give an alert to the subjects who are sitting on wheelchairs as reminder for them to start doing push up or weight shift activities. Each subject will have different time interval because the pressure occurs based on posture of the sitting and skin structure. This system is capable to use with any kind of cushion and no modification of remaining wheelchair use by the subject.

Lastly, the prototype system will be tested on acute and SCI subject to determine their feedback for future project improvement.

1.4 GENERAL CONCEPT

This project is aimed to design a low cost pressure ulcer prevention system specially used for acute SCI paraplegic subjects. As mentioned in international guidelines, they have been recommended to perform the pressure relieving activities such as push up. Since the paraplegic subjects are paralyzed in both legs, they still have strength at the upper body to do the push up activities by extending their elbow against the seat or handle to lift their body up thus relieve the weight load off their buttocks area.

The system consists of the timer and time interval selection. The user can choose and set the times intervals from 10 minutes, 15 minutes, 20 minutes and 30 minutes.

The system starts working when the subject sitting on the wheelchair cushion. The LDR are working when light is not detected, then the timer will start counting and buzzer will beep when the time interval reach as set up earlier. Buzzer is used as alarm sounds to remind the subjects to perform the pressure relieve activities.

If the timer is set for 10 minutes, the timer will count until 10 minute. The buzzer will begin to beep after the 10 minutes and the subject have to start do push up. But, the buzzer remains beep if the subject did not do any body lifting activities. This process is being repeated after the subjects sit back on the wheelchair.

1.5 DESIGN SPECIFICATION

The system consists of electric circuit as control unit and will be placed on the wheelchair cushion. The electric circuit will cover by waterproof material to avoid the subject from any electrical shock. The LDR will be placed at a few areas on the cushion in which part of the buttock is most prominent for high pressure. The target users are paraplegic SCI subjects. The system is focused to train the habit of the SCI subjects to do the pressure relieve activities such as push up or weight shifting.

The end product system should be user friendly, simple, low cost, lightweight and harmless to the subjects. The surface of the system shall be smooth and comfortable for the subjects. The prototypes reliability is determined by its durability and the length of use. In case of the damage, the difficulty of repair also determines the reliability of the system. Selection of the most appropriate components and affordable cost are important during repair or replacements. The stability of the system should be concerned to make sure the subject is safe when using this system and is capable to carry out activities on wheelchair. Therefore, the placement of the circuit should not distract the overall activities on the wheelchair.

Table 0-1: Design Specification

Design Specification	(√/ X)
Thickness of the circuit, < 5 cm	
Safe and comfortable	
User-friendly	
Low cost, < RM 500	
Light-weight, < 2 kg	
Fit to wheelchair seat, 16” x16”	

2.0 LITERATURE REVIEW

Many researchers have study about the pressure ulcer especially for SCI subject. Most SCI subject is wheelchair-bound and most of their day is spent sitting on the wheelchair. The pressure was occurred when combination with shear force and/or friction. There are a lot of methods to prevent the pressure ulcer. Most researchers have conducted study about the wheelchair cushion, and the posture of the subject during sitting on wheelchair. Nowadays, a lot of technologies have developed to become a system that able to monitor and alert the pressure release at buttock area.

2.1 WHEELCHAIR CUSHION

Cushion is a device that helps to relieve the pressure on bony prominences by pillowing (Mark J., Robert, Dale L., Martin, Mark, & Joseph, 1996).The material and type of cushion is important during selecting for SCI subjects. Nowadays, a lot of cushions have been developed in order to control the pressure at bony prominence of the pelvis. Some researcher found that 47 % of pressure ulcer was detected mostly at ischial tuberosities (IT) and sacrum (KM, I, & DL, 1995). While selecting best cushion for SCI subject, we need to focus some of the element such as level of SCI subject either paraplegia or tetraplegia, on how the ability of the pressure relief, transfer mechanism and subject lifestyle. There have many material can be used to design the seat cushion either static or dynamic and added with upright, powered and reclined wheelchair (Mary Ann, Robert, Dalton, Keast, B.Mortenson, & Jo-Anne, 2009). Burns and Betz have conducted studies of the seat cushion from ROHO (dry flotation), Jay2 (gel) and Ergo dynamic (dynamic). In their study, they compared the pressure during upright sitting on IT. From the result, high pressure occurred during upright sitting at IT area than during back position for both ROHO and Jay 2 cushion. By comparing the material of the cushion, dry flotation making more pressure than gel cushion during upright sitting (SP & KL, 1999).

Besides that, Seymour and Lacefield studied that 8 different types of cushion which are gel, water, air-filled, alternating pressure, foam, and durafoam. They investigated the relation between the type of cushion with pressure and temperature effect. From their result, air-filled cushion provided the best pressure reading while alternating pressure and foam cushion showed higher temperature reading among all groups. This result may lead to the formation of pressure ulcer because of increases in tissue susceptibility (RJ & WE, 1986).

Recently, many researchers started studying about the pressure release with different types of cushion. A study by Tanimoto, H, H, & H, 1998, choose five different types of cushion which are air cushion, cubic cushion, silicone gel cushion, contour cushion and polyurethane foam cushion (figure 2.1: material of cushion). Each type of cushion, have different kind of material to reduce the pressure. The air cushion contains a lot of rubber cells that different with cubic cushion consists of foam cells and silicone gel cushion made from silicone gel. They have calculated total weight, high pressure area, and maximum and average pressure to evaluate the function of the cushions. From their studies, they found that air cushion is the best of five cushions in pressure distribution. In the air cushion, the maximum pressure is influenced by the total weight, contact area and quantity of air in the cushion. They have shown that the maximum pressure was influenced by total weight and total area.

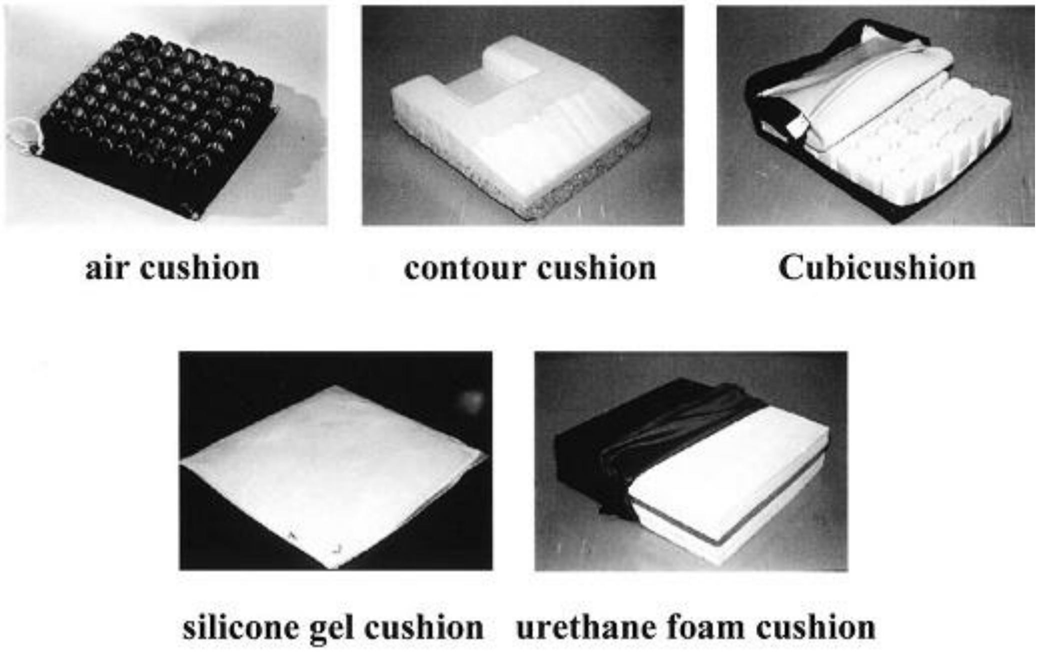

Figure 0-1: Material of cushion. Adapted from “The study of pressure distribution in sitting position on cushions for subject with SCI”, by Yoshio Tanimoto, Takechi H, Nagahata H, Yamamoto H, October 1998, *IEEE Transactions on instrumentation and measurement, 47*

In short, we can conclude that, the cushion is the important element that able to help the SCI subject to reduce the pressure ulcer. Seat cushion can help subject to prevent the ulcer become worse. Nowadays, a lot of subjects use air cushion for their entire life (Tanimoto, H, H, & H, 1998). The air cushion also already proved that given the lower pressure compare to other type of cushion.

2.2 POSTURE OF BODY

Abnormal pelvic position is one of the factors that contribute the pressure on the buttock area, which affect the skin integrity and subject will feel discomfort and pain (A.May, Butt, Kolbinson, Minor, & Tulloch, 2004). In other perfection, sitting with pelvic obliquity and loss of the lumbar lordosis are two important causes of development pressure ulcer. Sixty per cent of pressure occurred at ischial tuberosities (IT) and sacrococcygeal region for paraplegic subjects (D, 1988). Besides that, it was found that paraplegic subject mostly sitting with pelvis obliquity and load over the IT. Pelvis obliquity can contribute to the pressure at buttock area. Postural adjustment with proper back support is helpful to restore the pelvic position, improve trunk stability and increase comfort (A.May, Butt, Kolbinson, Minor, & Tulloch, 2004).

Terry, MPhil, Arthur, & Y.L,1996, investigated the posture effect on development of pressure ulcer. They have used a few different of posture and evaluated by using the pressure measurement equipment. They requested six paraplegic subjects to do a few posture sitting on wheelchair such as mid line posture, trunk bent left posture, trunk bent right posture, upright mid line posture ,forward trunk flexion posture and slump posture (figure 2.2: schematic diagram). From the study, they found that increasing the IT pressure during upright mid line posture and lower pressure during forward trunk flexion posture. They also study about that the different cushion type with different posture of sitting. The forward trunk flexion posture showed lowest IT pressure for every type if cushion. But for ROHO and PU foam cushion showed that highest IT pressure during mid-line posture. From every type of cushion, they were concluded that ROHO is more efficient with effect of sitting posture. The sitting posture is one of the factors that contribute the pelvic orientation and ischial pressure.

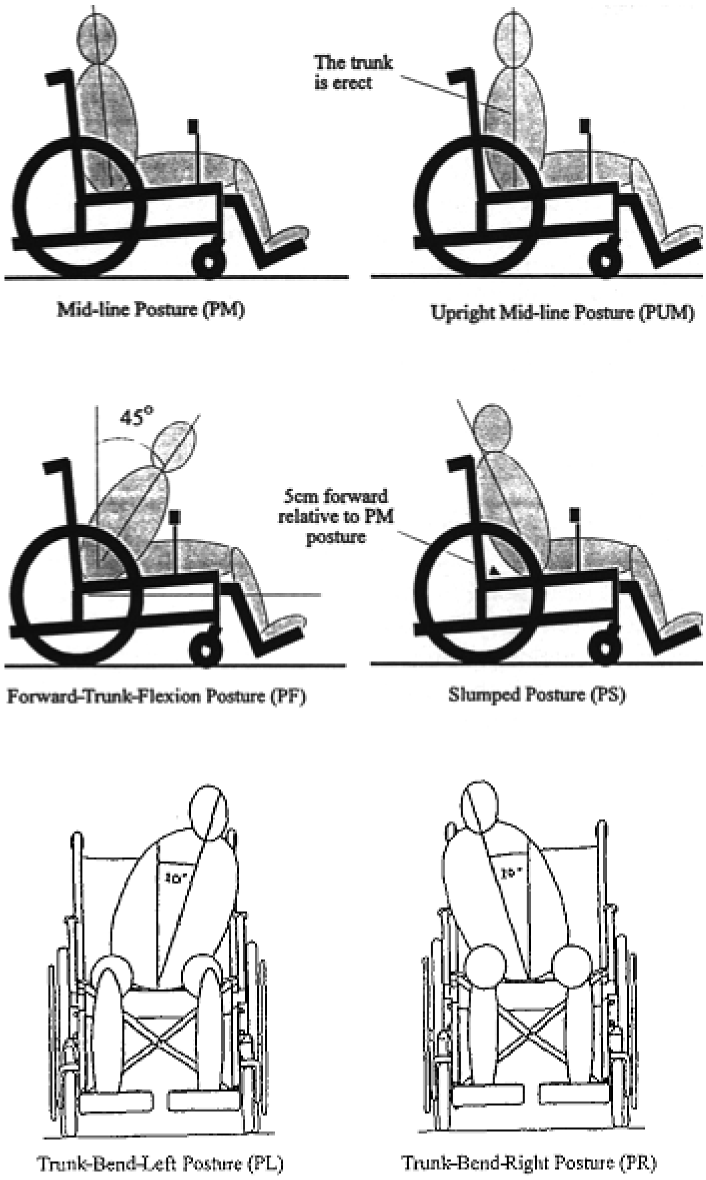

Figure 0-1: Schematic diagram of sitting posture. Adapted from "Posture effect on seating interface biomechanics: comparison between two seating cushion", by Terry K. Koo,MPhil, Arthur F.T.Mak ,Y.L.Lee, January 1996,*Arch Phys Med Rehab II, 77.*

2.3 PRESSURE MEASUREMENT TECHNOLOGIES

The system is used to monitor the pressure ulcer that relief during system on the wheelchair. There are a few technologies already available in the market. Most hospital was used this equipment as the assessment tool to analyze the duration and area of pressure ulcer especially for SCI subject (M.Brienza, E.Karg, Greyer, Kelsey, & Trefler, 2011).

The system consists of sensor that measures the pressure over the buttock area. Electronic (capacitive, resistive, strain gauge), pneumatic and electro-pneumatic is the type of sensor that can be used to measure the interface pressure. The sensing element where attach with electronic transducer. The applied force can be measureable which resulting in resistance or capacitance (E.Gyi, Porter, & Robertson, 1998).

While pneumatic sensor is air cell connected with air reservoir. If pressure in air reservoir exceed the applied to sensor, it will expand the sensor. The volume of air in the sensor will increase if inflation pressure rises above applied pressure. The pressure in the air reservoir at which the changes of the pressure increases is recorded as applied interface pressure. The electro-pneumatic sensor consists of electrical contact on inner surface of flexible sac. Then air is pumped into sac. When internal and external pressure is equal, electrical contract will breaks and pressure at this point is recorded as interface pressure (E.Gyi, Porter, & Robertson, 1998).

According to Bennett studies, he developed the sensor that capable to measure the pressure, shear force and blood flow. The sensor was coming with two pressure, one shear and one blood flow. The size of sensor used only 2.5 cm (Bennett, L.Kavner, D.Lee, Trainor, & F.A, 1979). K, Koester, D.Bush, & S, 1995, was used the sensor manufactured by Tekscan. The sensor is thin and flexible with consists of grid. This sensor measures the pressure by change of electrical resistance.

According to Cascioli, Liu, I.Heusch, & Carthy, 2011, the pressure was relief because of discomfort during seating and no appropriate support was used. In his study, the force sensing resistor was placed at four areas in cushion for detection the pressure. (Figure2.3 showed the placement of sensor and measurement).

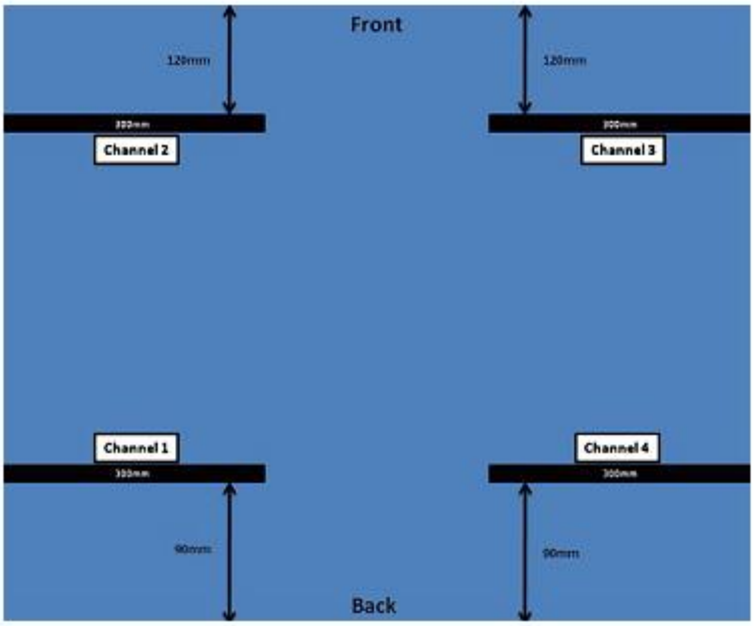

Figure 0-1: The schematic drawing of placement sensor on the cushion for assessment pressure relief. Adapted from “Settling down time following initial sitting and its relationship with comfort and discomfort”, by Vincenzo Cascioli, Zhuofu Liu, Andrew I. heusch, Peter W.M Carthy, 2011, *Journal of tissue viability, 20*.

2.4 PRESSURE RECORD DEVICE

The pressure device was developed by Davies, which capable to record the time to start doing exercise and capable to record the time during using the wheelchair. The design contains switch placed at wheelchair cushion and connected with logic circuit (figure 2.4). The objective of this device is to become the routine assessment of the subject’s exercise in future (M.W, I.C, J.B, & J.C, 1980).

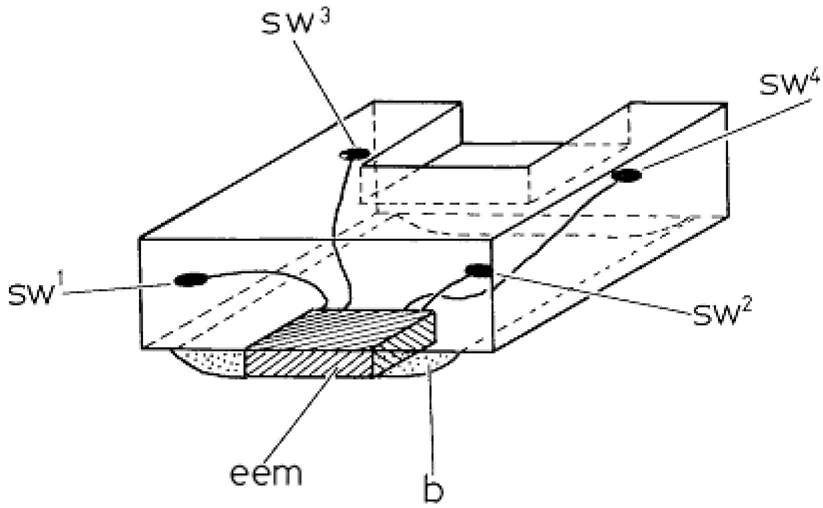

Figure 0-1: Illustration of the pressure device that consists of switch (SW) placed on wheelchair cushion with electronic exercise monitor (eem). Adapted from "Pressure Sore prevention for the wheelchair-bound spinal injury subject", by M.W. Ferguson-Pell, I.C. Wilkie,J.B. Reswick, J.C. Barbenel,1980,*Paraplegia,18*.

2.5 APPLICATION OF THERMAL IMAGING

From research by Hahn and Black, they had investigated using thermal imaging as assessment of subject support. They have been measure the thermal response of the skin with use of support (M.W, I.C, J.B, & J.C, 1980).

2.6 PRESSURE ALERT SYSTEM

Vonne, June 2013, was developed and tested of a new wheelchair cushion system to prevent pressure ulcer on spinal cord injury (SCI) patients. She has developed cushion that integrated with electronic circuit that consists of RC circuit . The design concept of her research to give an alarm to remind subject to start performing pressure relief exercise. The system consists of compression spring that trigger the switch sensor to complete the circuit and buzzer will beep after 15 minutes.

2.7 COMMERCIAL PRODUCT

One of the devices that already commercialize in the international market which capable to prevent the pressure ulcer for spinal cord injury subject (figure 2.5: The system of TexiCare). The system is mounted on user wheelchair and consists of 100% textile sensor. The sensor is capable to measure the pressure at interface between the cushion and buttock area. The system connected to a cigarette box sized that capable to measure the pressure in real time, estimate the risk for internal over-strains and give an alert to wheelchair user. It is based on a tactile-visual feedback, the tactile modality is used to discreetly alarm the subject while the visual modality conveys an information messages. There have been tested to paraplegic volunteer about 6 months. They have found out that, the bad habit such as inadequate posture during watching TV and result the abnormal high pressure. They were aim that their system capable to help subject monitor their interface pressure and prevent the pressure ulcers (Chenu, Vuillerme, Bucki, Diot, Cannard, & Payan, 2013).

Figure 0-1: a) the placement of Texicare map on wheelchair cushion, b) The device that connected to Texicare map, c) Texicare textile. Adapted from “TexiCare: An innovative embedded device for pressure ulcer prevention. Preliminary results with a paraplegic volunteer”, by Olivier Chenu, Nicolas Vuillerme, Marek Bucki, Bruno Diot, Francis Cannard, Yohan Payan,2013, *Journal of tissue viability, 22*

2.8 CONCLUSION

Based on what we have reviewed, we can conclude that the development of pressure ulcer always occurs for SCI subjects that sitting on wheelchair for their entire life. Furthermore, to manage the pressure ulcer that is costly, a lot of studies have presented variable methods of preventing pressure ulcer. There were three effective methods in preventive the pressure ulcer which is wheelchair cushion, posture of sitting and pressure relieve activities such as push up or body weight shifting. However, the most effective method and less costly are by doing pressure relieve activities such as push up and weight shifting. Nevertheless, to train the subject habits especially the acute SCI subject may consume a long time. We propose the pressure prevention system that is capable of giving an alert to subjects as the most effective way in order to make sure the subject perform the pressure relieve activities every single day. In designing this system, the most important part is electric circuit that consists of timer, buzzer and sensor. The system should be capable to run and safety to use by the subject.

3.0 METHODOLOGY

3.1 PROJECT DEVELOPMENT PLANNING

In developing design, there are elements that need to be highlighted which are human, technology, environments, and cost effectiveness. All of these elements had become main focus in order to realize this project and can be commercialized in assistive technology device market. For human factor, we cater individuals with spinal cord injury, paralyzed on lower body and have capability to do rehab activity such as push up and body weight lifting and also subject who use wheelchair in their daily life. In technology factor, we are going to create device that can be commercialized and system that user friendly. From the physical specification, this device is lightweight, in line with wheelchair actual size that is 16”x 16” x2”, easy to store and mobile. It will also ease the clinician to handle this device. As of the environment factor, this device can be accessed either at home or workplace. Furthermore, it is also reliable and accessible when using the public transport. In the development of this device, we also focus in the cost effectiveness. This device has been designed using the technology that can be afforded to all level of subject because it is cheaper than other assistive technology in the current market. The reason why all of these elements had become the main focus is it has strong relationship and correlation between each element that being used.

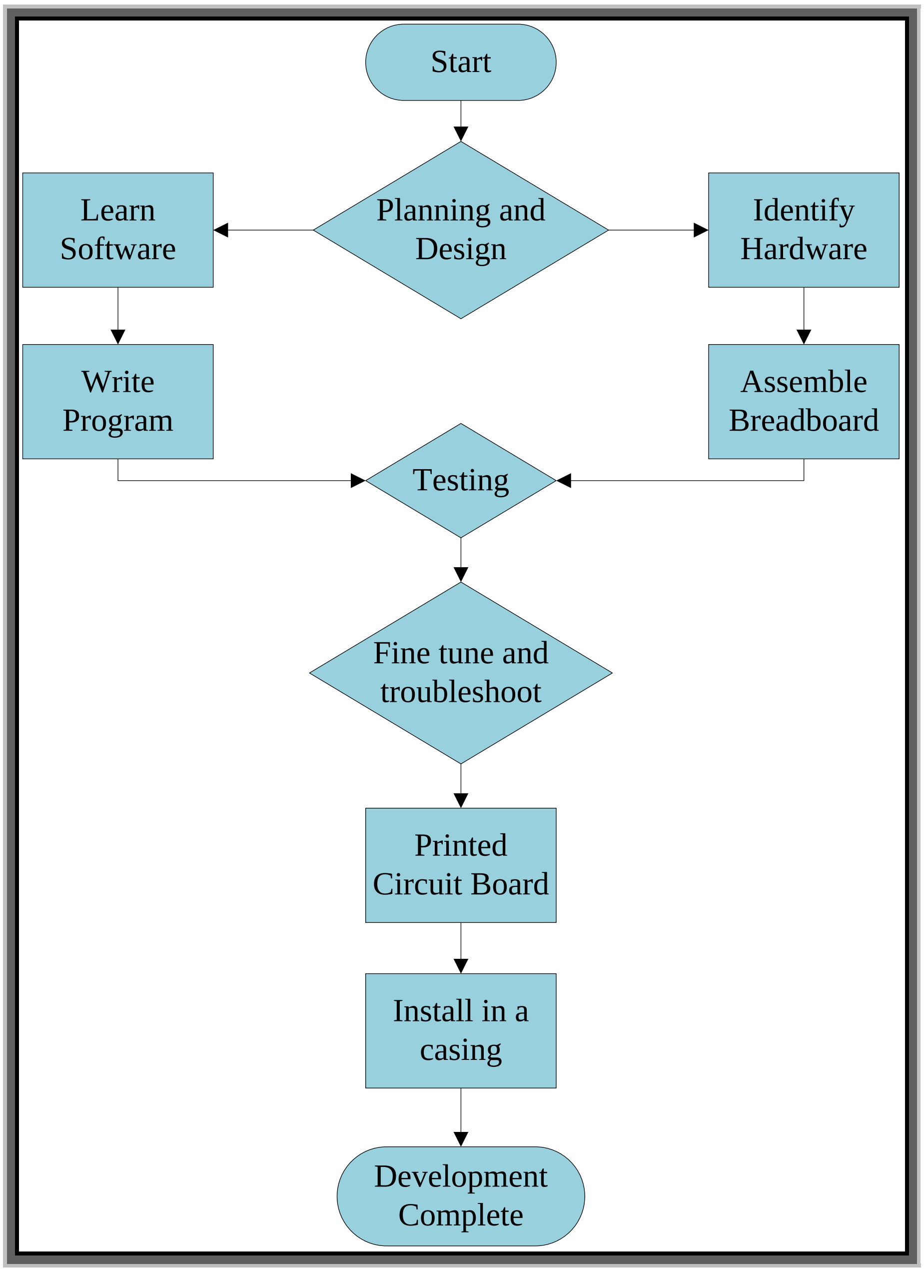

Figure 0-1: Project development flow chart

Figure 3.1 shows that the flows chart of prototype development. From the chart the activities consists of two parts. The first part is about learning the software. In this project C-compiler was used to create the program. Then PICkit2 software used to read and write the HEX from C-compiler software into PIC16F877A microcontroller. After successful, the PCB was designed and print out in A4 size.

3.2 DESIGN SPECIFICATION

The following are the specification of the design system deliberated to make sure the planning is successful;

3.2.1 SENSOR TECHNOLOGY

For this developed system, Light Dependent Resistor (LDR) is used as the sensing element to make sure the control system is functioning. LDR system is dependent on light. In this system, when voltage that pass through more than 3 volt, and the LDR did not expose to the light, system will start counting the time that has been selected. In this project, eight (8) LDR has been embedded in the surface of cushion. LDR sorted in series because when at least one (1) of the LDR when being not exposed to light, the system will automatically count-down the time. It will trigger the buzzer at control system to beep and give the signal to the subject to start doing the body lifting activities such as push up. The sensor area was covered with transparent material to avoid any liquid to come into the cushion. This is one of the safety features that we consider to make sure subject is safe using the device and no any electric shock that able to harm the subjects.

3.2.2 CONTROL SYSTEM

The control system consist of 3 buttons, which the first button is for setting, second button for selecting the time interval and the third button is for start button for the control system to begin time counting. Other than that, at the control system, it also has a buzzer as an indicator to trigger the subject to do body lifting activity. The control system is powered by a 12 volt battery to make sure it easy to be used at any place. This system also has LCD panel that displays the time counting to assist subject and clinician to monitor time duration.

3.2.3 SEATING SYSTEM

The dimension of our cushion is the same with wheelchair's area of seating. For the internal material, foam has been used and for the external, waterproofs cover was used to protect the foam and circuitry from any. Foam cushion was selected because of their material that is capable to adapt into any shape, given support and distributes pressure across the sitting surface. Another reason choosing this material, as mentioned earlier, the material of the foam can adapt with any shape because we will insert the sensor into the foam cushion. In this case, the particular selected foam was the actual foam materials used for spinal cord wheelchair cushion. The physical dimensions of the cushion is 16'x16"x2" following the dimension of the standard cushion size.

3.3 DESIGN CRITERIA

There are few design criteria that have been identified which have the significance and importance to design the system technology. (Cooper, 1995)

3.3.1 AFFORDABILITY

The system is estimated to cost below than RM500. This is to make sure every subject is able to own this system. This is because, subjects who seriously have this illness to own the special cushion and undergo the operation, the cost is believed to be higher than this system.

3.3.2 COMPATIBILITY

This system is suitable to be used for all kinds of wheelchair because it is purposely design to make the dimension same with seating area of wheelchair. Besides, it is suitable to be used for all age level of subject as long as they have ability to do body lifting activity.

3.3.3 DEPENDABILITY

This system can be repeatedly and continuously used by the subject without being assisted by someone else because once the subject seat on the cushion and the system start counting, buzzer will beep and subject start doing activity and when the subject seat, the system will count again.

3.3.4 DURABILITY

This system is expected to be used for long time because the sensor has been placed at the surface of the cushion so that it will face less pressure and the tendency to defect is lower than using pressure sensor which easy to lose its sensitivity.

3.3.5 EASY TO ASSEMBLE

This system designed only consist control system and cushion so that when to operate in the wheelchair just place the cushion and start system. Furthermore, this system also can be operated in bed and normal chair.

3.3.6 EASY OF MAINTENANCE

The cushion can be maintained and clean using the liquid but it must be avoided from contacting liquid to the electronic circuit. Other than that, the cost for maintenance is cheaper because the component that being used easy to find in market and the cost is not too high just around RM 1.50 per unit.

3.3.7 PERSONAL ACCEPTABILITY

This system is has been designed to make sure the subject can use it independently without assistant. On top of that, this system assist subject to create habit to do body lifting activity.

3.3.8 PHYSICAL COMFORT

The cushion has been used did not change the actual position during on the wheelchair. It did not make the subject feel discomfort and feel like seating in normal wheelchair. Other than that, the cushion also has waterproof cover to avoid subjects from feeling discomfort due to their bodily fluid and to avoid it from being absorbed into the electronic circuit.

3.4 FLOW OF THE PROJECT

This project will be focused in two sections. The first section is development of electrical component that consist of timer, buzzer and sensing element while the second section is testing the prototype device to new SCI subject.

Each subject has different time for pressure occur and is also dependent on with their skin structure. However, for this project evaluation, all subjects were set up as default in 15 minute.

The testing will take for subject to familiar with the device. One survey form will be given to them as the feedback for this project. Project objective can be proven after result from the test has been obtained.

3.5 FLOW OF THE SYSTEM

The device starts by pushing the start button. The time was set as default in 15 minute. After that, subject will sit on the wheelchair. The load will be detected by the LDR and will trigger the timer to start count.

When the time is reach, buzzer will beep as alert to the subject to start doing the exercise. The buzzer will stop when the subject sit back onto wheelchair. The timer starts recount again, the system will continue and buzzer will beep after the time done countdown. The system will stop when the subject turn off the start button. Flow chart of the system shows in figure 3.2

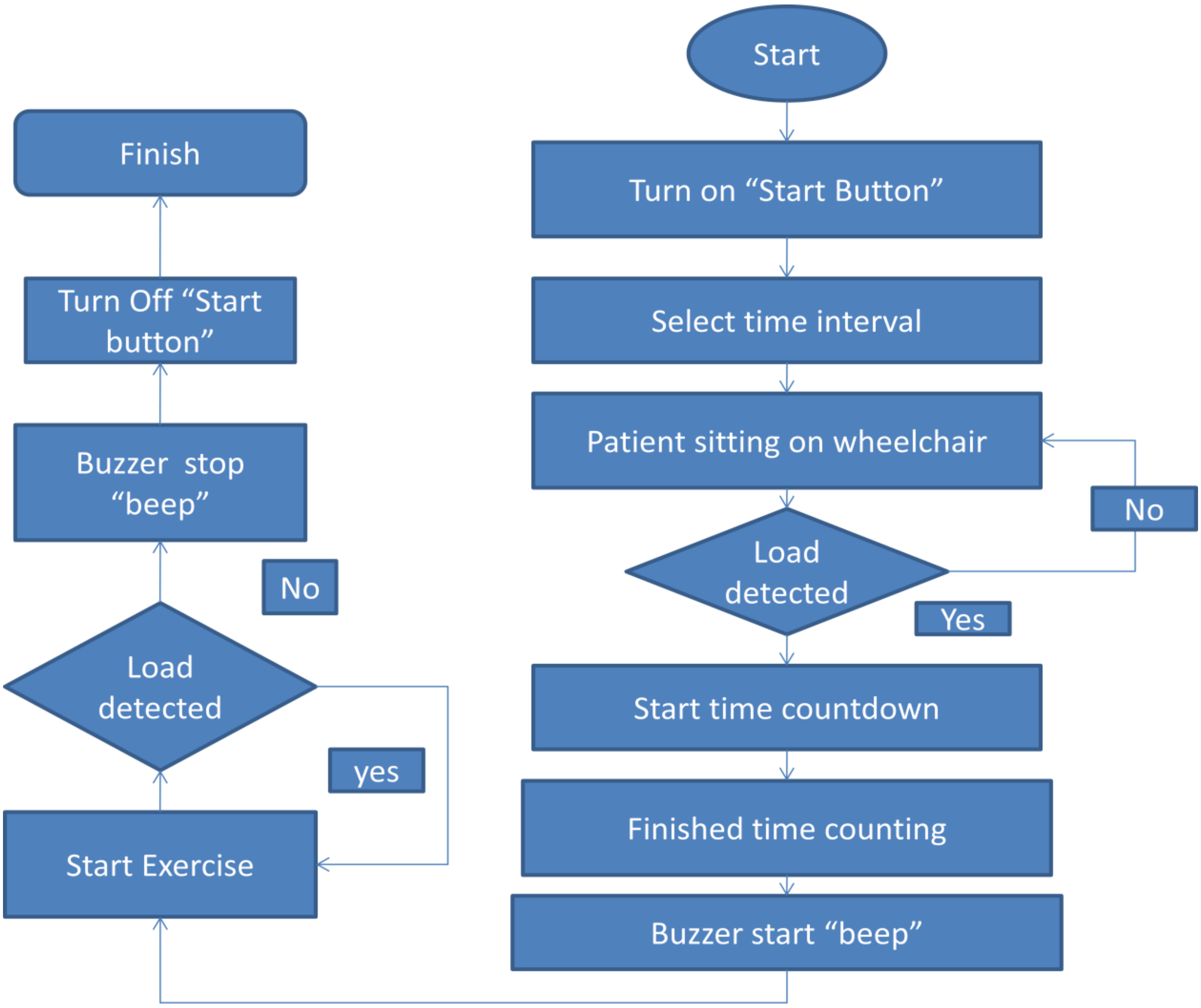

Figure 0-1: Flow of the system

3.6 PROJECT BLOCK DIAGRAM

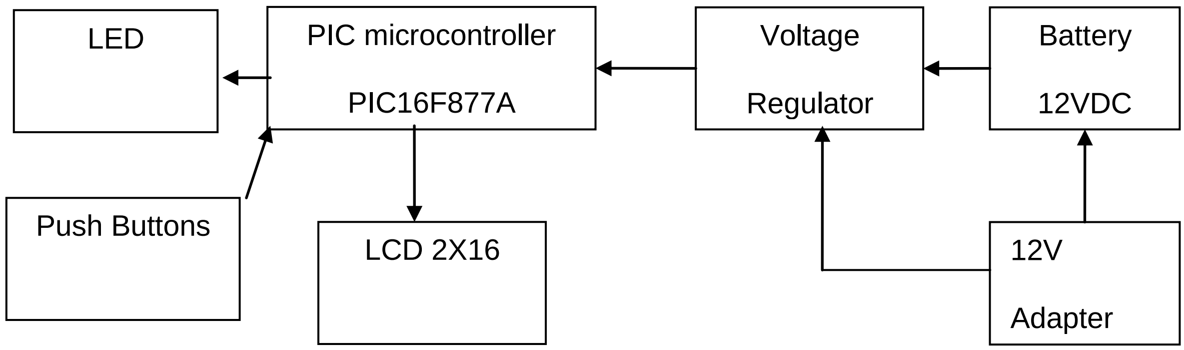

Figure 0-1: Project block diagram

Figure 3.3 show the project block diagram. The PIC16F877A-I/P microcontroller is used to control the whole system. The PIC can operate using 4.5V to 6.0V DC voltage. In the project is operating at 5.0V. While, the voltage regulator module is used to protect PIC and other connected sensors / actuators from over voltage. This is because PIC and all other connected sensors, actuators all support 5V DC only. Over voltage will cause any of the module burn.

3.7 ELECTRIC CIRCUIT DIAGRAM

In the figure 3.4 and 3.5 shows the circuit diagram of the system the microcontroller connected with the plurality of sensing elements, a timer, and an alert means; a voltage regulator connected to the microcontroller and the plurality of sensing elements to regulate voltage of the pressure relief training system; a display panel connected to the microcontroller to display a pre-set time interval. Sensing elements detects no light exposed onto the pad when the user is seated on the pad, thereby activating the timer according to the pre-set time interval; wherein the alert means alerts the user when the pre-set time interval is reached. While in figure 3.5 shows the circuit for power supply. For this system, 12 v batteries were used to complete the system running. This prototype also can be operated by using adapter.

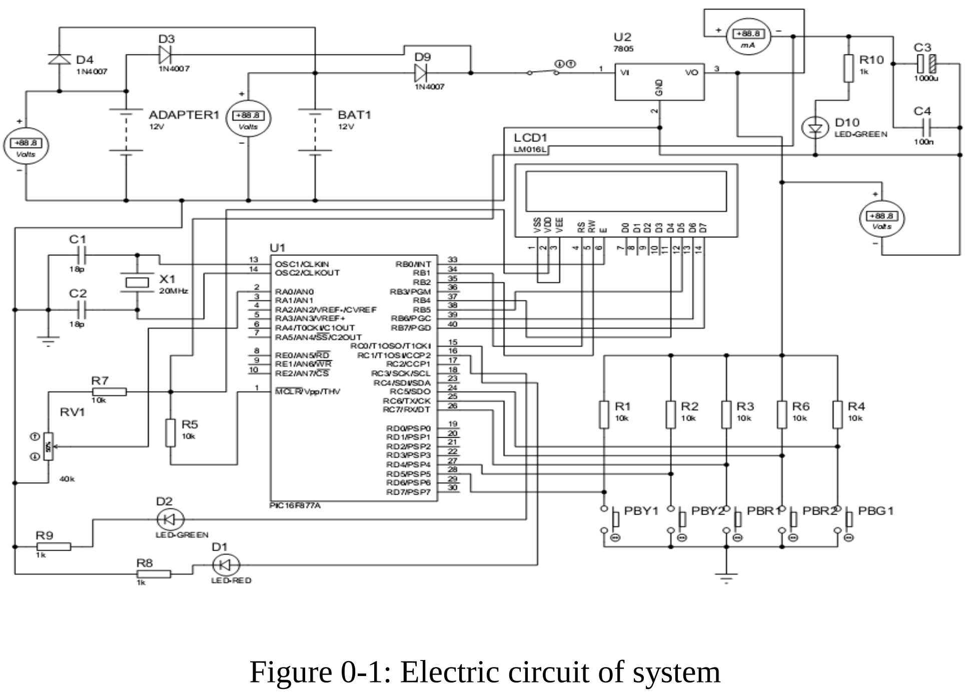

Figure 0-1: Electric circuit of system

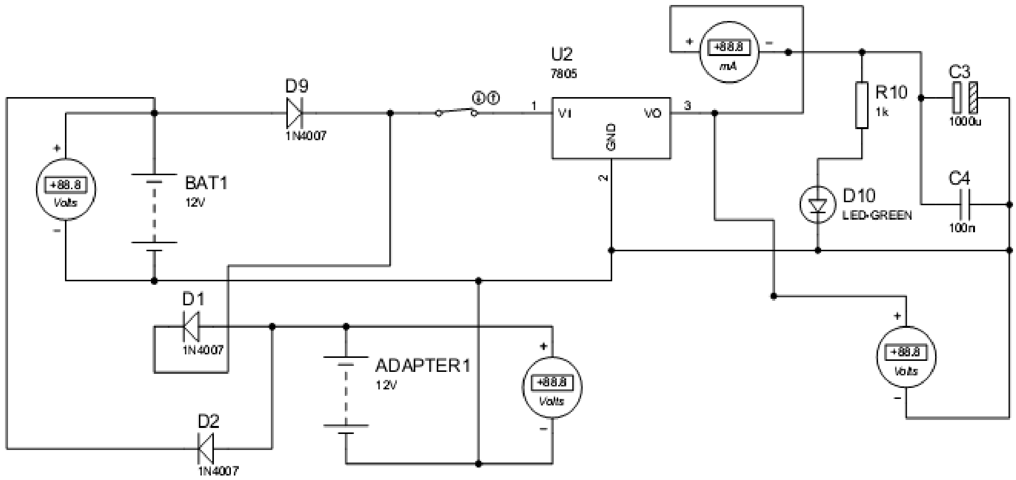

Figure 0-2: Power supply circuit

3.8 ELECTRONIC COMPONENTS

3.8.1 PIC 16F877A MICROCONTROLLER

Figure 0-1: PIC16F877A

First is about Microcontroller PIC16F877A (figure 3.6). It is one amongst the PICMicro Family microcontroller that is common at this moment, begin from beginner until all professionals. As a result of very simple using PIC16F877A and use flash memory technology in order that may be write-erase till thousand times. The prevalence this RISC Microcontroller compared to with different microcontroller 8-bit particularly at a speed of and it code compression. PIC16F877A have 40 pin by 33 path of I/O.

Other than that, EEPROM memory makes it easier to use microcontrollers to devices wherever permanent storage of varied parameters is required codes for transmitters, motor speed, receiver frequencies, etc. Furthermore, its low cost, low consumption, simple handling and suppleness create PIC16F877A applicable even in areas wherever microcontrollers had not previously been thought of, for example timer functions, interface replacement in larger systems, coprocessor applications, etc. In System Programmability of this chip, along with using solely 2 pins in information transfer makes attainable the flexibility of a product, when collecting and testing are completed. This capability may be used to produce assembly-line production, to store activity data accessible only when final testing or it may be used to improve programs on finished product.

3.8.1.1 PROGRAMMING DEVELOPMENT TOOLS

There are 3 programming development tools that will be used in this project. First is PCW C-Compiler. Its function is to edit and compile C-language program. It will generate .hex file for downloading application. Second is PICKIT2 Downloader Software and this software is used to download program to PIC. This software comes with Microchip USB PIC Programmer. Last is about PICKIT2 Universal PIC Programmer. It is an electronics device used to download PIC program into PIC. Through PICKIT2 downloader software, this programmer can download PIC program (machine code, .hex file) into PIC.

3.8.2 VOLTAGE REGULATOR MODULE

Figure 0-1: Voltage regulator module

Second component is voltage regulator module (figure 3.7). This module used to regulate voltage in the system and at the same time will protect the PIC and other connected sensor from over voltage because it is only supports 5V DC only. In this project, LM7805 will be used to regulate the voltage in the system have 5V DC output. LM7805 module supports voltage from 7V DC to 18V DC. On the other hand, if it faces the over voltage situation it will burn or will have auto shutdown. Furthermore, to avoid high frequency oscillation on the outputs which may cause system hand or unstable, the generated 5V will be filtered by 0.1uF ceramic capacitor and a 100uF electrolytic capacitor. In addition, to make sure that voltage connected correct, it will have a diode at the input of LM7805. Other than that, it has on/off switch to turn on/off the system and have LED to indicate the system is on/off.

3.8.3 HD44780 CHARACTER LCD

Figure 0-1: LCD

Next is the usage of HD44780 character LCD (figure 3.8). It is use to display device designed for interfacing with embedded system. This character LCD uses a standard 14 pin interface and 16 pin for backlights. It can operate in 4 bit or 8 bit mode display. For 4 bit pins 7 through 10 are unused and the entire byte is sent to the screen using pins 11 through 14 by sending 4 bits at a time.

3.8.4 LIGHT DEPENDENT RESISTOR (LDR)

Figure 0-1: LDR

For this system, the sensor that will be used is light dependent resistor (LDR) (figure 3.9).LDR is a type of resistor whose working depends upon only when exposed to the light. The resistor performs as per amount of light and its output directly differs with it. In general, LDR resistances is minimum or ideally zero when it receives maximum amount of light and goes to maximum or ideally infinite when there is no light falling on it. When the light level is low the resistance of the LDR is high. This prevents current from flowing to the base of the transistors. Consequently the LED does not light.

However, when light shines onto the LDR its resistance falls and current flows into the base of the first transistor and then the second transistor. The LED lights. The preset resistor can be turned up or down to increase or decrease resistance, in this way it can make the circuit more or less sensitive.

3.8.5 OUTPUT LED

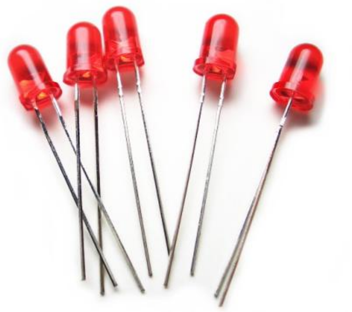

Figure 0-1: LED

In this project LED (figure 3.10) will be used as one of the component in the circuit. A normal LED use 5V and 5mA to operate and through LED the current status of the system can be known. A 1KR resistor is connected series with the LED to limit the current pass through LED is 5mA. This is calculated using V=IR. Where V=5VDC, R=1KR.

3.9 COST ESTIMATION

Table 0-1: Cost Estimation of development of the system

Description	Value	Quantity	Unit Price (RM)	Total (RM)
Microcontroller	PIC16F877A	1	27.00	27.00
Crystal	20MHz	1	1.20	1.20
Capacitor	18pF	2	0.30	0.60
Voltage Regulator	LM7805	1	1.20	1.20
Capacitor	0.1uF, 50V	1	0.30	0.30
Capacitor	1000Uf, 16V	1	1.00	1.00
Diode	1N4007	1	0.20	0.20
Switch	On/Off	1	2.00	2.00
Resistor	10KR, 1/4W, 5%	3	0.05	0.15
Resistor	1KR, 1/4W, 5%	2	0.05	0.10
Connector	Pin Header, 1*40	1	0.80	0.80
IC Socket	40 pin	2	0.80	1.60
LED	5mm	2	0.20	0.40
LCD	2*16, Green	1	30.00	30.00
Push Button	Metal type	3	3.00	9.00
LDR	5mm diameter	8	1.50	12.00
Battery	12VDC, 1.2AH	1	40.00	40.00
PCB	300mm*150mm	1	50.00	50.00
Total				**177.55**

3.10 DRAWING OF THE SYSTEM DESIGN

Figure 3.11 and 3.12 shows the drawing schematic of the control system and location of the sensor placement. The control system consists of three push button used to setting the time interval and start or stops the system. Sensor was placement mostly at buttock area, which most pressure ulcer occurs.

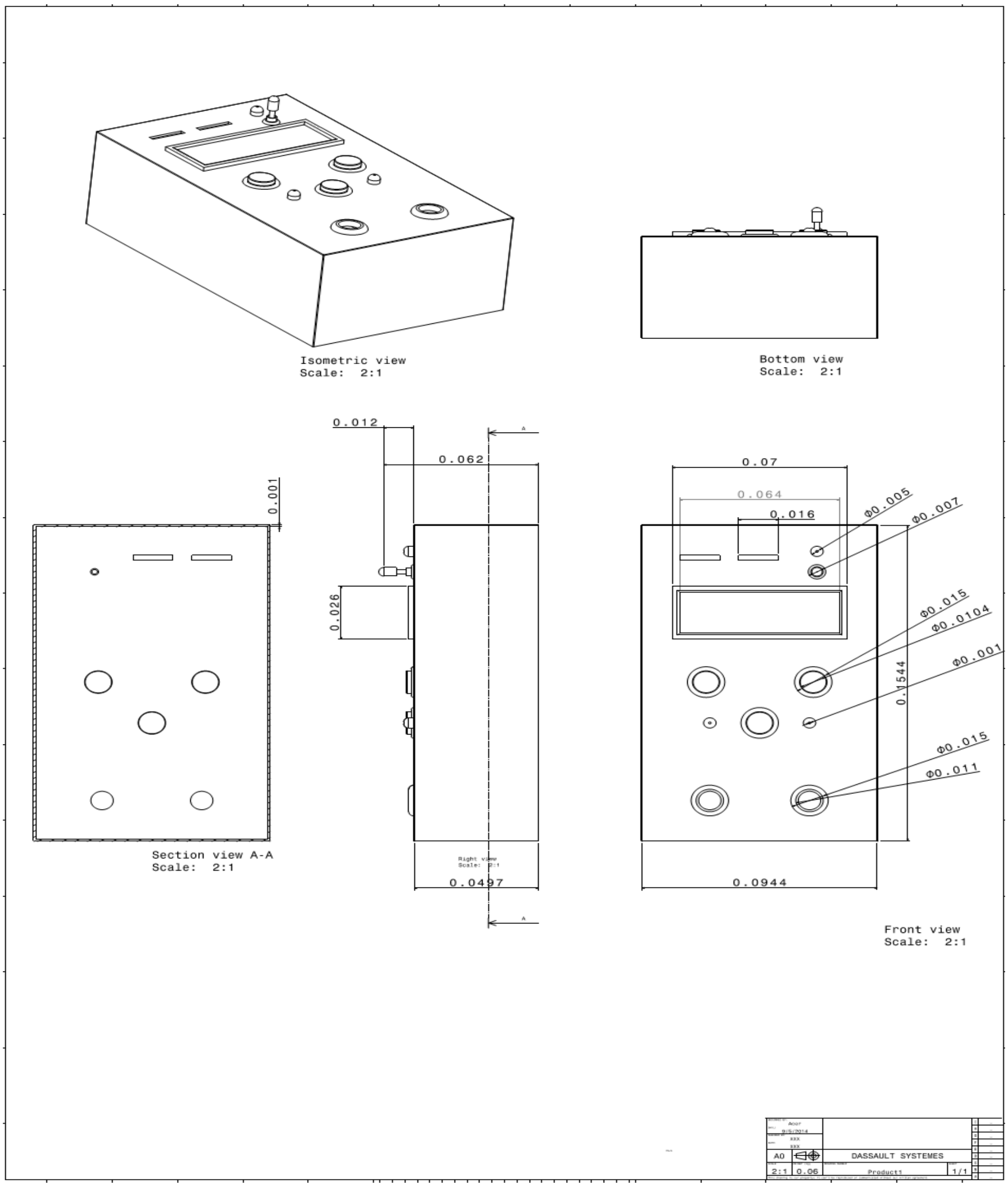

Figure 0-1: The design of the control system

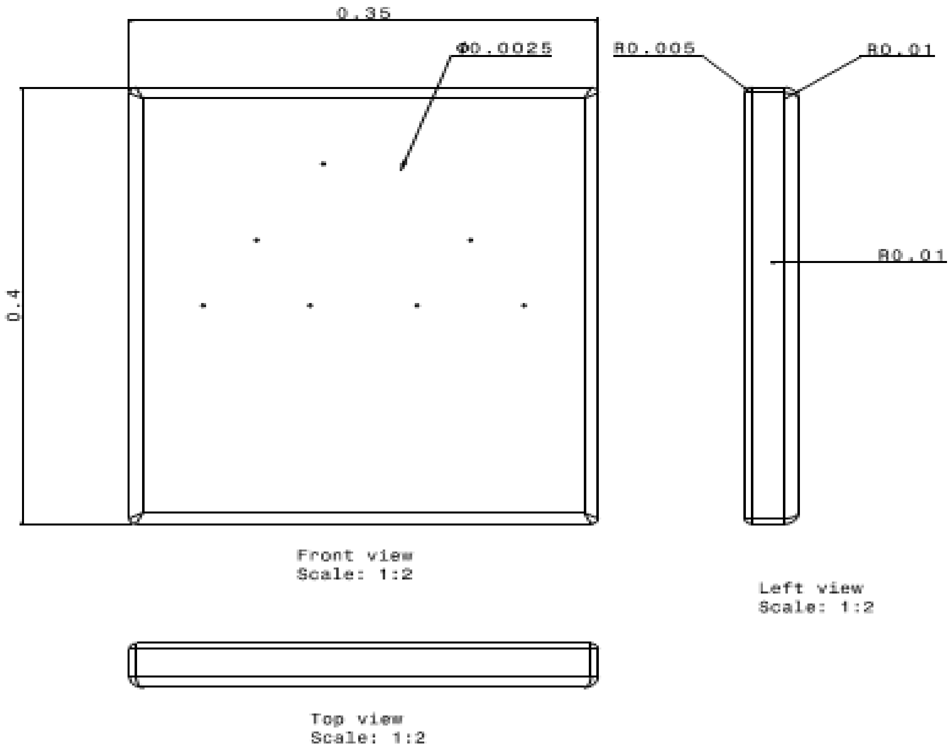

Figure 0-2: Placement of the sensor on the wheelchair cushion

3.11 INSTALLATION OF CUSHION INTO WHEELCHAIR

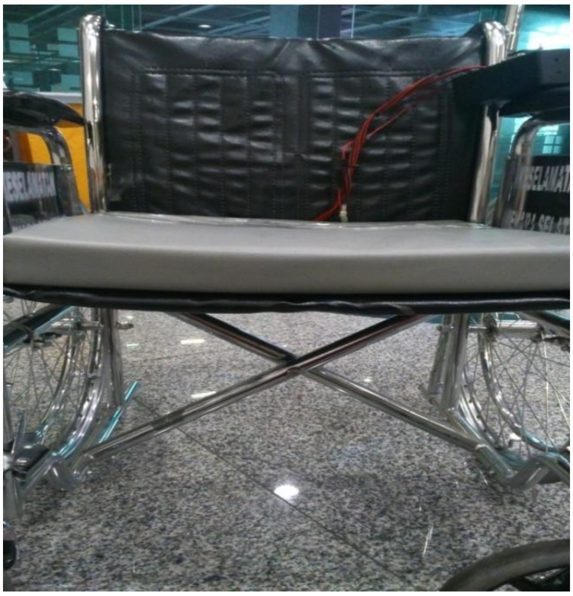

Figure 0-1: Front view

Figure 0-2: Top view

Figure 3.13 and 3.14 shows the placement of the cushion that consists of sensor using the standard wheelchair at front and top view. The cushion was fixed with any type of wheelchair. The control system was placed behind the wheelchair.

3.12 DEVICE EVALUATION

Ethic approval was obtained by the Pusat Perubatan Universiti Malaya (PPUM) to get the permission for the device to be tested on the subjects who have their treatment at PPUM (refer Appendix D). Subjects have been provided with Quebec user evaluation of satisfaction with assistive technology (QUEST) form in order to get their feedback on the device specification (refer Appendix F). Besides that, subject also has been provided with others survey (refer Appendix G) form to get their feedback in term of functionality of the system. Consent form also distribute to all subject as part of the ethics procedure.

Seven SCI subjects participated in the testing of this device. The subjects were of both acute and chronic SCIs. Subject’s age is around 19 to 50 years old and each of them who are involved had experiences and knowledge about pressure relief activity. Every subject has been given the information about the survey and the device testing was conducted for 15 minutes each in subject. It has followed the guideline of pressure ulcer prevention for persons in wheelchair that stated that it should be done at least 15 minutes. All subjects who participated in this testing have the strength in the upper body to make sure that they were capable of performing wheelchair push up.

4.0 RESULT

Product testing has been done for this system in two levels. First is testing on individual component of the system. Second is testing with the subject.

4.1 DEVICE TESTING

4.1.1 MEASUREMENT OF SYSTEM CHARACTERISTIC

The result showed that the system successfully ran. This was verified by the LDR being functional when exposed to normal light and when not expose to the light. Furthermore, the time counted operated as what being set at the beginning of the activity. The buzzer beeped when time count finished as what being set. To prove this system successful, some of the LDR was cover from exposed the light and timer start counting (figure 4.1 & 4.2). When release of LDR, in other word exposed to light, timer stop counting.

Figure 0-1: The default setting of the system 10 minute, button green used to adjust the required setting.

Figure 0-2: The timer start counting after LDR is not exposed to light.

4.1.2 DEVICE PERFORMANCE

The system was being tested and the results were successful when started doing push up activities. Furthermore, is also has been tested with different time interval which are 10, 15, 20, 25, and 30 minutes. Besides that, to prove that system is robust and durable, it has been tested 10, 15, 20, 25, and 30 minutes simultaneously and it has been found that the system can operate well. Furthermore, impact test has been done and was found that the sensor was still in good and normal condition.

4.2 PRODUCT EVALUATION BY THE USER

4.2.1 CONTROL SYSTEM

When the time has been set for 15 minutes for each subject, the test will start (figure 4.3). After 15 minutes had passed, buzzer beeped and subjects start doing push up (figure 4.4). From this test, system was successfully proved that in 15 minutes, buzzer beeped and subject does the push up. The buzzer stops beeping when subjects start the push up but there are some subjects that unable to do perfect push up and the buzzer keep on beeping. The obtained data are tabulated in the table 4.1.

Figure 0-1: The cushion that consists of LDR placed on to wheelchair sitting area.

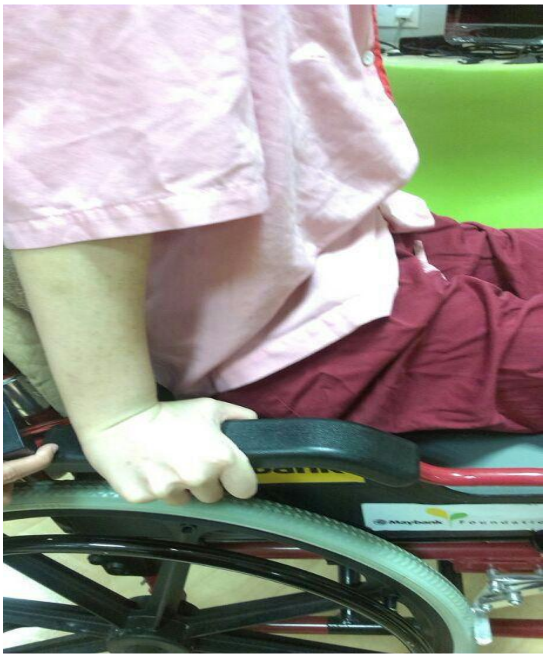

Figure 0-2: The subject doing push up after buzzer beep.

Table 0-1: Data collected during testing the system with all subjects

Subject	Gender	Race	Chronic/Acute	Age (years)	Buzzer beep	Capable of wheelchair push up
1	Male	Chinese	Chronic	55	√	√
2	Male	Malay	Chronic	40	√	X
3	Male	Chinese	Chronic	41	√	X
4	Female	Chinese	Acute	24	√	√
5	Male	Indian	Chronic	64	√	X
6	Male	Malay	Acute	19	√	√
7	Female	Chinese	Acute	26	√	√

X= buzzer beeping

- Chronic= two years and above, Acute= up to 6 weeks after sub acute and rehabilitation phase

4.2.2 USER EVALUATION FEEDBACK

From the QUEST survey, the subjects were required to choose 3 items that were considered to give the most satisfaction from the device. From the result, 100% agreed that device's safety is important, while the remaining choices come from comfortable, durability and easy to be used. Safety has become patients' main aspect that has been chosen by patients because LDR has been installed in the cushion. If the circuit is not designed properly, it has tendency to expose subjects with electric shock.

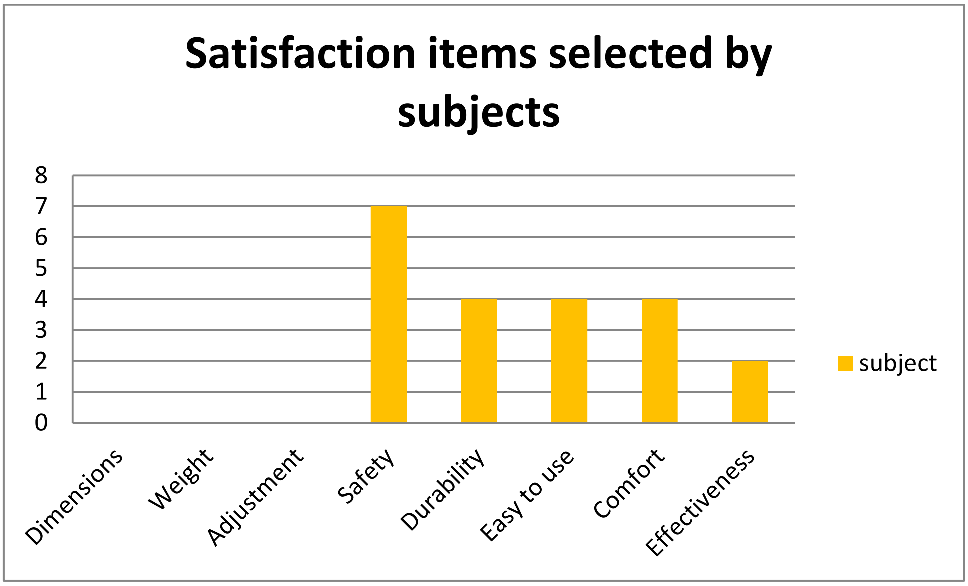

Figure 0-1: Satisfaction items selected by subjects

4.2.3 SELECTION OF BODY WEIGHT SHIFTING PREFERENCE

There are two options to do the body shifting activities which are wheelchair push up and lateral weight shift. From seven subjects who had performed this test, two subjects choose to do lateral weight shift. This is because, they do not have the upper body strength to do the push up. From this test, it has been observed that buzzer always beeping because subjects cannot do perfect push up. While the other subjects choose wheelchair push up because they have upper body strength to do the push up. The results are shown in the figure 4.6.

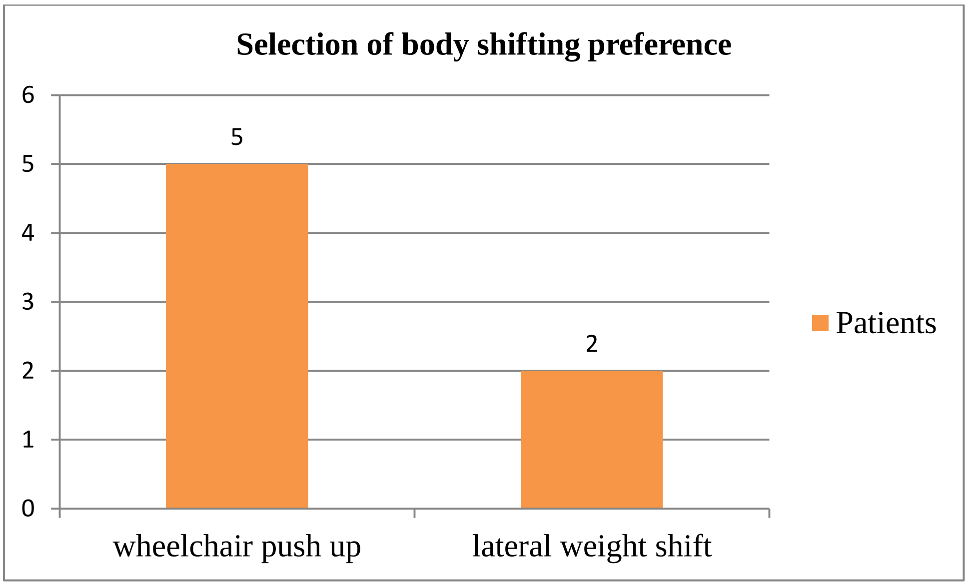

Figure 0-1: Selection of body shifting preference

4.2.4 SELECTION OF DURATION TO PERFORM WHEELCHAIR PUSH UP

In term of time selection in doing wheelchair push up, about 71% (n=5) of the subjects had chosen to do the push up in 30 seconds while 29 % (n=2) had chosen to do 20 seconds. Subjects can do push up for 30 seconds because they have enough strength to do the push up. There are also subjects that have experiences to do the push up. Another 29 % select 20 second because they cannot do the push up longer and starts to fatigue. This is because when doing push up, upper body need to support whole weight of the subjects. The result is shown in figure 4.7.

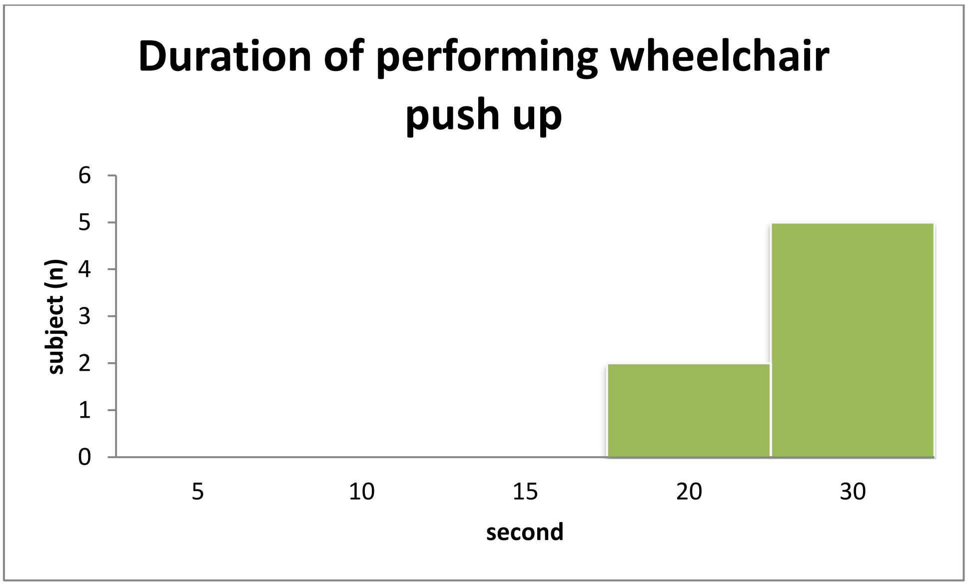

Figure 0-1: Selection of duration to perform wheelchair push up

4.2.5 SELECTION OF TIME FOR BUZZER BEEPING

Most of the subjects choose to do wheelchair push up every 30 minutes and they do not agree to 15 minutes as being stated in the guideline. There is some subject that familiar with push up thinks that 15 minute is too soon. Testing using 15 minutes suitable for the subject that still in the rehab program and cannot able to determine level of pressure or suitable time to do pressure relief activities. The result is shown in figure 4.8.

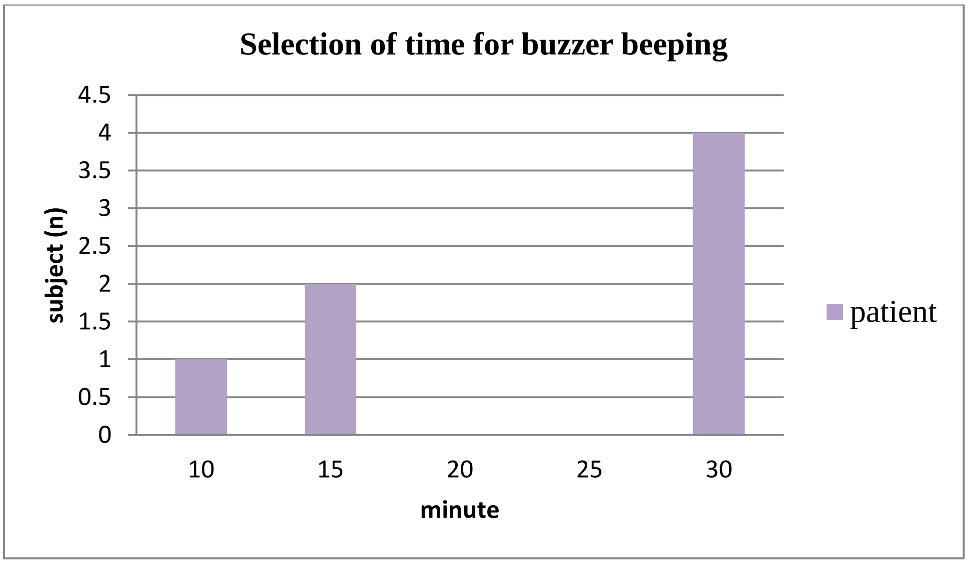

Figure 0-1: Selection of time for buzzer beeping

4.2.6 WILLINGNESS TO BUY THE DEVICE

All of the subjects also have been instructed to give their opinions if this device being entered into market, are they will buy it or not. From the survey, 71% (n=5) of subjects agreed that they will buy this device. While, there are some subjects that disagree that they will buy this device because they think that this device is not effective for them. This contradict with the first group of respondents, i.e the other 71 % (n=5) who think that this device can help them in giving alert to do the activity especially when they at home. With this device, it can create habit for them to do pressure relief activity. The 71% that agreed are the acute patients and remaining 29% that disagreed are the chronic patient. Result is shown in figure 4.8.

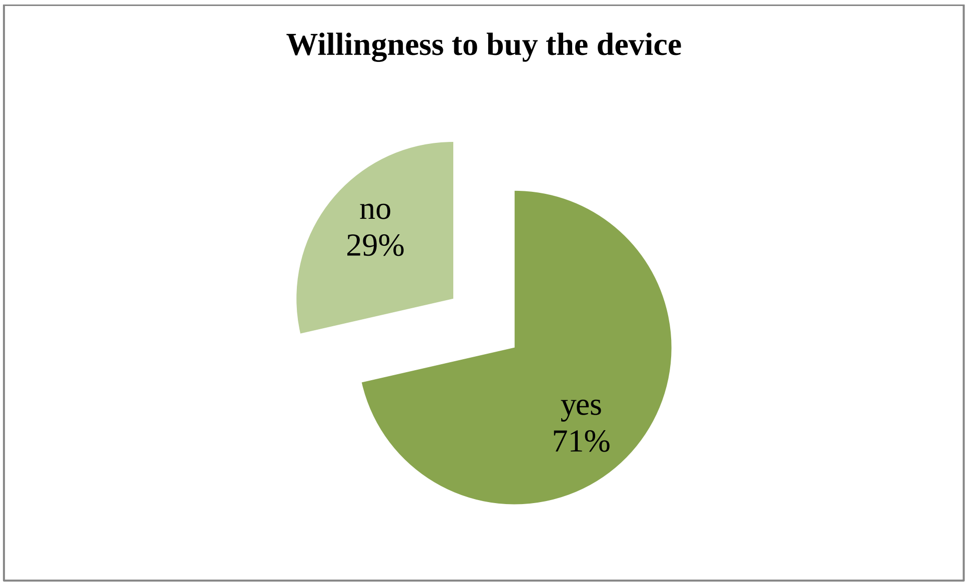

Figure 0-1: Willingness to buy the device

5.0 DISCUSSION

5.1 QUALITY OF LIFE

Cost of creating this device is not too high if to be compared with other methods which are cushion and plastic surgery. By involving patients and technology usage, financial aspect will play the main role in creating device that can be used will various levels of patients to be compared with the cost of purchasing cushion and plastic surgery. Generally, there are three methods of pressure relief activity, which are pressure relief activity, good quality of cushion and plastic surgery can reduce and cure the pressure ulcer, but it must be seen in the durability. Good quality of cushion such as ROHO that value more than RM1000 but it's only have less than 3 years of durability. For plastic surgery, according to US statistic the cost is around RM200, 000 and it is still need further treatment after the surgery. It can be concluded that pressure relief activity can help patients to prevent pressure ulcer with the cost around RM300 and also increased quality of life. On top of that, this device do not requires long time to be used. This is because, when the patients' habit has been created, they do not have to use this device anymore. Pressure ulcer might be occurred, but the duration can be reduced.

Table 0-1: Comparison of three types of preventive

Type of preventive	Pressure relief activities	Good quality of cushion	Plastic Surgery
Cost (RM)	**300 ++** (based on manufacturer cost)	**1000 ++** (based on ROHO brand)	**200,000 ++** (based on US statistic)

5.2 OVERALL PRODUCT DESIGN

The device that has been designed is ergonomic in term of physical measurement. This device can be held with only one hand which helps the patient to install the device. Other than that, the button that is use to set the time, was designed in large size to make patients easier to use the button. Furthermore, this device using cushion that have the exact size with wheelchair and this device also can be used in normal chair and patients will have options when using this device.

5.3 COMPARISON WITH OTHERS PRODUCT

There are various researchers that produced thesis to develop device that able to help SCI patient in order to prevent pressure ulcer. One of the sensor technologies that have been used is textile sensor that its function to measure pressure between buttock and cushion area. Meanwhile for long term, material's sensor that being used can be easily dysfunction because of the impact when patient sat on it. On top of that, the sensor only triggers the alarm when there is only measurement pressure. The pressure is very subjective because every patient has their own time to produce the sensor. Besides that, pressure can be reduced with the good quality of cushion and good posture during sitting. Other researcher use switch sensor that trigger from compression spring. The device has weakness because when cushion being changed its design to be higher than usual, it can make patient feel uncomfortable and unstable. It can be concluded, usage of LDR can be mechanism in giving alert to patient to perform pressure relief activity and LDR also have material that resist impact and can be used in a long time.

Table 0-1: Summary of comparison on functional of sensor

Type	Textile sensor	Switch sensor	LDR
Trigger Alarm System	Yes	Yes	Yes
Condition	Depend on pressure between buttocks and cushion area.	Depend on compression of spring.	Depend on light.

5.4 OUTCOME FROM PRODUCT EVALUATION

Based on the test has been done, we can conclude that the development of this device can assist patient to do preventive pressure ulcer. As mentioned earlier, there are two significant strategists that been effective way to prevent pressure ulcer, but only one that being focused are doing push up every 15-30 minutes. As being stated in the guideline, every person on wheelchair has to do shift weight every 15 minutes (Jonathan, Karen, Darryl, Kevin, & Sherry, 1995). This activity can be successfully done if patients have the ability and strength of upper body. Meanwhile, patients still have options because there are three methods that can be used in order to do pressure relief activities which are push up, lateral weight shift and forward learn weight shift. On top of that, duration to do pressure relief activity is the most criteria that need to be considered and based on the study that has been done, it is recommended that the time needed for tissue reperfusion in SCI is around 15-30 second (Stephen & Sharon, November 2011).

From the result that has been obtained, the device capable to alert patient to start doing pressure relief activities and time that being set as default is about 15 minutes to every subject tested by the device. After 15 minutes subject started doing activities, it was found that there have some subjects that did not capable to do the perfect push up, buzzer still beeping and that is mean subject yet to be lifted the cushion. This is limitation of the device that only capable to do push up rather other way of the activities such as lateral weight shift and forward weight shift.

Another thing to be highlighted is about the alert system. In this development, buzzer used to give alert but some subject feels that buzzer was too loud and not comfortable. In that case, some amendment can be done by changing an alert system by using vibration or visual alarm that send to the subject by using mobile phone. It will make subject more comfortable during using the device. Furthermore, the buzzer used has no setting for how long the beeping. Actually, in other study it has been mentioned that subject need to do push up around 15-30 second (Stephen & Sharon, November 2011). It will be better if buzzer beeping around 15-30 second and after that subject will sit back. This buzzer is not only giving an alert and also counting to do push up.

In sensor system, LDR is very helpful in giving alert to the subject. That's also prove that by using sensor, timer counted and buzzer beeped but in safety features, it's needed to design the placement of sensor to be more secure in order to prevent the liquid absorb into cushion. From this time being, sensor covered by transparent material to avoid liquid absorbed. Subject feels insecure with device and worry for electrical shock. Another focus is programming the sensor, it was programmed for push up activities which mean when all the sensors exposed to the light, buzzer will stop beep. In future, sensor should be programmed to make it able to be used for lateral weight and forward weight shift or in simple word, at least one LDR that exposed to light, buzzer stop beeping.

Other limitation from this test, a few subjects involved is old SCI patient and already familiar with pressure relief activities. From the feedback, subjects feel that the device is not required since they have capability to detect when pressure will going to happen and know how much duration needed to do push up. For acute patients that still under rehab program, this device is useful to give alert to start doing the pressure relief activities.

5.5 CONCLUSION

From this development, we can discussed that an alert system capable to remind and create patients' habit to do the pressure relief activities. Since pressure relief activities is one of the effective ways to prevent pressure ulcer. Some limitations can be eliminated in future development to make the device more reliable to patients.

6.0 CONCLUSION

The development of prevention system is believed to be able to help acute SCI paraplegic subjects and aid them in their rehabilitation process. It also can improve their quality of their life by training the subjects in preventing the pressure ulcer thus reduces pressure ulcer.

This device development had achieved its objective. It has been proving that with this device, it will help subject to create their habit to do pressure relief activities. Besides that, the development of the system has fulfilled the design specification as showed in table 6.1.

Table 0-1: Achievement of design specification

Design Specification	(√/ X)
Thickness of the circuit, < 5 cm	√
Safe and comfortable	√
User-friendly	√
Low cost, < RM 500	√
Light-weight, < 2 kg	√
Fit to wheelchair seat, 16" x16"	√

As we highlighted at the beginning, pressure relief activities can help the subject to reduce their pressure ulcer. There are two solutions in managing the pressure ulcer which are good quality cushion and undergo the operation of ulcer area. But, we have find out that pressure relief activity help subject in term of cost effectiveness and have positive outcome. In this project, we created an alert system that capable to helps subject in build and maintain their habit to do the pressure relief activity. In term of marketing the device to commercialized , survey have been asking to subject if the system is ready in market whether they are going to buy. They are given a positive feedback, will buying if available. After doing the calculation of manufacturing cost, the device can be commercialized with cost per unit around RM 350.00 as shown in table 6.2. This cost is below the expected estimation at early of the development.

Table 0-2: Total cost manufacturing and market cost per unit

Component	Units	Price (RM)
Foam cushion (16"x16"x2")	1	60.00
PVC cushion cover	1	25.00
Electronic components	-	177.55
Labour cost	-	50.00
Total manufacturing cost/unit	-	**312.55**
Cost/unit sold	-	**350.00**

On the other hand, there are weaknesses that need to be considered in order to make sure that the outcome from this device becomes better. This is because, from the sensor's design, it has been set up in series. Actually there is some disadvantagebecause it will affect all LDR if one of the LDR became faulty. It also makes difficulty in troubleshooting which LDR that have the problem. But in term of cost for repairing, is lower that using other sensor. The cost for buying one LDR sensor is around RM 1.50 per unit.

There is improvement that can be done in order to make sure this device become more effective, with device that equipped with pressure indicator. From this indicator, we can identify the pressure level of every subject during sitting on wheelchair. On top of that, when having this indicator, time interval is not longer being used because buzzer will beep when the pressure level is increased and in the serious pressure and subject starts to do pressure relief activity.

Furthermore, in order to make sure the security of this project development and to prevent from being copied by others, it has been applied to be patented and succeed into innovation stage for this application

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8.0 APPENDICES

APPENDIX A: DATA SHEET PIC 16F87X

PIC16F87X

28/40-Pin 8-Bit CMOS FLASH Microcontrollers

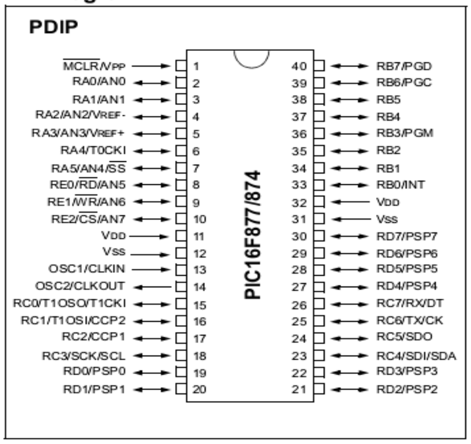
Devices Included in this Data Sheet:

- PIC16F873
- PIC16F874
- PIC16F876
- PIC16F877

Microcontroller Core Features:

- High performance RISC CPU
- Only 35 single word instructions to learn
- All single cycle instructions except for program branches which are two cycle
- Operating speed: DC - 20 MHz clock input
  DC - 200 ns instruction cycle
- Up to 8K x 14 words of FLASH Program Memory,
  Up to 368 x 8 bytes of Data Memory (RAM)
  Up to 256 x 8 bytes of EEPROM Data Memory
- Pinout compatible to the PIC16C73B/74B/76/77
- Interrupt capability (up to 14 sources)
- Eight level deep hardware stack
- Direct, indirect and relative addressing modes
- Power-on Reset (POR)
- Power-up Timer (PWRT) and Oscillator Start-up Timer (OST)
- Watchdog Timer (WDT) with its own on-chip RC oscillator for reliable operation
- Programmable code protection
- Power saving SLEEP mode
- Selectable oscillator options
- Low power, high speed CMOS FLASH/EEPROM technology
- Fully static design
- In-Circuit Serial Programming™ (ICSP) via two pins
- Single 5V In-Circuit Serial Programming capability
- In-Circuit Debugging via two pins
- Processor read/write access to program memory
- Wide operating voltage range: 2.0V to 5.5V
- High Sink/Source Current: 25 mA
- Commercial, Industrial and Extended temperature ranges
- Low-power consumption:
  - < 0.6 mA typical @ 3V, 4 MHz
  - 20 µA typical @ 3V, 32 kHz
  - < 1 µA typical standby current

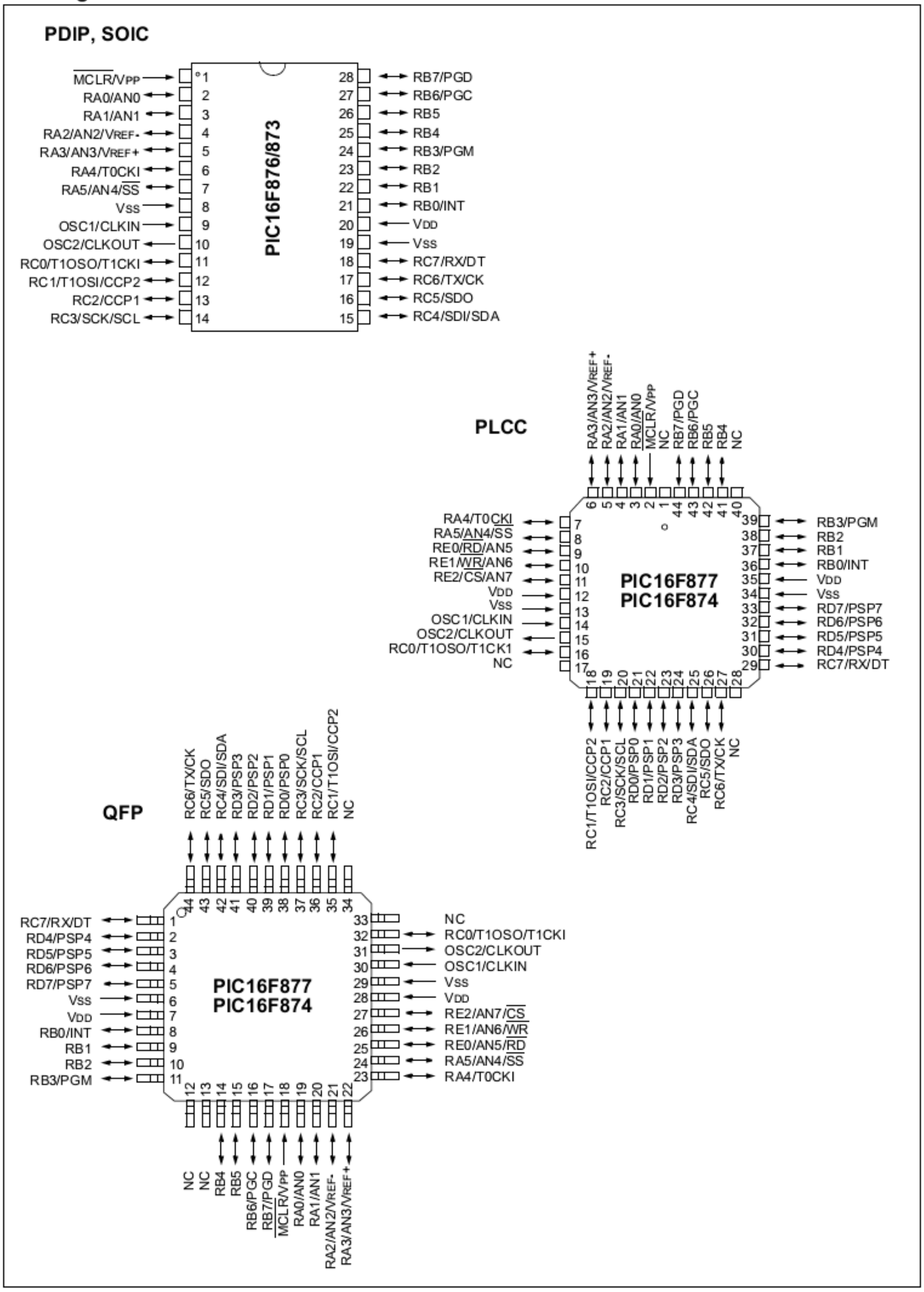
Pin Diagram



Peripheral Features:

- Timer0: 8-bit timer/counter with 8-bit prescaler
- Timer1: 16-bit timer/counter with prescaler, can be incremented during SLEEP via external crystal/clock
- Timer2: 8-bit timer/counter with 8-bit period register, prescaler and postscaler
- Two Capture, Compare, PWM modules
  - Capture is 16-bit, max. resolution is 12.5 ns
  - Compare is 16-bit, max. resolution is 200 ns
  - PWM max. resolution is 10-bit
- 10-bit multi-channel Analog-to-Digital converter
- Synchronous Serial Port (SSP) with SPI™ (Master mode) and I^{2}C™ (Master/Slave)
- Universal Synchronous Asynchronous Receiver Transmitter (USART/SCI) with 9-bit address detection
- Parallel Slave Port (PSP) 8-bits wide, with external RD, WR and CS controls (40/44-pin only)
- Brown-out detection circuitry for Brown-out Reset (BOR)

Pin Diagrams



Key Features PICmicro™ Mid-Range Reference Manual (DS33023)	PIC16F873	PIC16F874	PIC16F876	PIC16F877
Operating Frequency	DC - 20 MHz	DC - 20 MHz	DC - 20 MHz	DC - 20 MHz
RESETS (and Delays)	POR, BOR (PWRT, OST)	POR, BOR (PWRT, OST)	POR, BOR (PWRT, OST)	POR, BOR (PWRT, OST)
FLASH Program Memory (14-bit words)	4K	4K	8K	8K
Data Memory (bytes)	192	192	368	368
EEPROM Data Memory	128	128	256	256
Interrupts	13	14	13	14
I/O Ports	Ports A,B,C	Ports A,B,C,D,E	Ports A,B,C	Ports A,B,C,D,E
Timers	3	3	3	3
Capture/Compare/PWM Modules	2	2	2	2
Serial Communications	MSSP, USART	MSSP, USART	MSSP, USART	MSSP, USART
Parallel Communications	—	PSP	—	PSP
10-bit Analog-to-Digital Module	5 input channels	8 input channels	5 input channels	8 input channels
Instruction Set	35 instructions	35 instructions	35 instructions	35 instructions

APPENDIX B: DATA SHEET VOLTAGE REGULATOR LM 7805

National Semiconductor

September 2001

LM340/LM78XX Series 3-Terminal Positive Regulators

General Description

The LM140/LM340A/LM340/LM7800C monolithic 3-terminal positive voltage regulators employ internal current-limiting, thermal shutdown and safe-area compensation, making them essentially indestructible. If adequate heat sinking is provided, they can deliver over 1.0A output current. They are intended as fixed voltage regulators in a wide range of applications including local (on-card) regulation for elimination of noise and distribution problems associated with single-point regulation. In addition to use as fixed voltage regulators, these devices can be used with external components to obtain adjustable output voltages and currents.

Considerable effort was expended to make the entire series of regulators easy to use and minimize the number of external components. It is not necessary to bypass the output, although this does improve transient response. Input bypassing is needed only if the regulator is located far from the filter capacitor of the power supply.

The 5V, 12V, and 15V regulator options are available in the steel TO-3 power package. The LM340A/LM340/LM7800C series is available in the TO-220 plastic power package, and the LM340-5.0 is available in the SOT-223 package, as well as the LM340-5.0 and LM340-12 in the surface-mount TO-263 package.

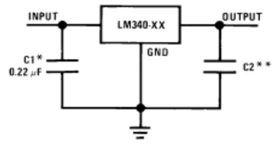
Features

- Complete specifications at 1A load
- Output voltage tolerances of ±2% at T_j = 25°C and ±4% over the temperature range (LM340A)
- Line regulation of 0.01% of V_{OUT}/V of ΔV_{IN} at 1A load (LM340A)
- Load regulation of 0.3% of V_{OUT}/A (LM340A)
- Internal thermal overload protection
- Internal short-circuit current limit
- Output transistor safe area protection
- P^+ Product Enhancement tested

Device	Output Voltages	Packages
LM140	5, 12, 15	TO-3 (K)
LM340A/LM340	5, 12, 15	TO-3 (K), TO-220 (T), SOT-223 (MP), TO-263 (S) (5V and 12V only)
LM7800C	5, 8, 12, 15	TO-220 (T)

Typical Applications

Fixed Output Regulator



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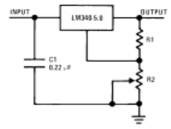
*Required if the regulator is located far from the power supply filter.

**Although no output capacitor is needed for stability, it does help transient response. (If needed, use 0.1 μF, ceramic disc).

Adjustable Output Regulator



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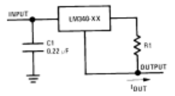
V_{OUT} = 5V + (5V/R1 + I_Q) R2 5V/R1 > 3 I_Q,
load regulation (L_r) ≈ [(R1 + R2)/R1] (L_r of LM340-5).

Current Regulator



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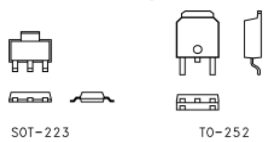
$$I_{OUT} = \frac{V2\text{-}3}{R1} + I_Q$$

ΔI_Q = 1.3 mA over line and load changes.

Comparison between SOT-223 and D-Pak (TO-252) Packages



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Scale 1:1

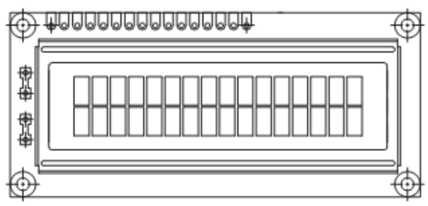
 DS007781 www.national.com

APPENDIX C: DATA SHEET LCD

LCD-016M002B

Vishay

16 x 2 Character LCD



FEATURES

- 5 x 8 dots with cursor
- Built-in controller (KS 0066 or Equivalent)
- + 5V power supply (Also available for + 3V)
- 1/16 duty cycle
- B/L to be driven by pin 1, pin 2 or pin 15, pin 16 or A.K (LED)
- N.V. optional for + 3V power supply

MECHANICAL DATA

ITEM	STANDARD VALUE	UNIT
Module Dimension	80.0 x 36.0	mm
Viewing Area	66.0 x 16.0	mm
Dot Size	0.56 x 0.66	mm
Character Size	2.96 x 5.56	mm

ABSOLUTE MAXIMUM RATING

ITEM	SYMBOL	STANDARD VALUE			UNIT
		MIN.	TYP.	MAX.	
Power Supply	VDD-VSS	- 0.3	–	7.0	V
Input Voltage	VI	- 0.3	–	VDD	V

NOTE: VSS = 0 Volt, VDD = 5.0 Volt

ELECTRICAL SPECIFICATIONS

ITEM	SYMBOL	CONDITION		STANDARD VALUE			UNIT
				MIN.	TYP.	MAX.	
Input Voltage	VDD	VDD = + 5V		4.7	5.0	5.3	V
		VDD = + 3V		2.7	3.0	5.3	V
Supply Current	IDD	VDD = 5V		–	1.2	3.0	mA
Recommended LC Driving Voltage for Normal Temp. Version Module	VDD - V0	- 20 °C		–	–	–	V
		0°C		4.2	4.8	5.1	
		25°C		3.8	4.2	4.6	
		50°C		3.6	4.0	4.4	
		70°C		–	–	–	
LED Forward Voltage	VF	25°C		–	4.2	4.6	V
LED Forward Current	IF	25°C	Array	–	130	260	mA
			Edge	–	20	40	
EL Power Supply Current	IEL	Vel = 110VAC:400Hz		–	–	5.0	mA

DISPLAY CHARACTER ADDRESS CODE:

Display Position	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
DD RAM Address	00	01														0F
DD RAM Address	40	41														4F