Design and Construction of a Movement Support Device for Transporting the Elderly or Patients with Leg Muscles Weakness between a Wheelchair, Bed, and Toilet for Home Use

Thanakorn Yootho* and Jaroonrut Prinyakupt

College of Biomedical Engineering, Rangsit University, Pathum Thani, Thailand
*Corresponding author, E-mail: thanakorn2f@hotmail.com

Abstract

The lifestyle of the elderly or patients with leg muscles weakness must use a wheelchair to transporting between the bed and toilet. Found problem was the transition between a wheelchair and bed or flush toilet, the elderly or patients must stand up and rotate the body to sit on a bed or flush toilet, and vice versa, they may be able to fall, resulting in other disadvantages followed. This research was intended to design and construction of a movement support device for transporting the elderly or patients with leg muscles weakness between a wheelchair, bed, and toilet for home use. The device can be transporting the elderly or patients with leg muscles weakness between a wheelchair, bed, and toilet, without standing up and rotate the body to sit on a bed, wheelchair or flush toilet which was the prevention of falls. This device composed of electronic systems and mechanics part. The electronics system was used to control the operation of a device. It consists of a microcontroller, h-bridge drivers, alarm with buzzer, limit switch, lithium-ion battery with charger and C language program. The mechanics part was designed and constructed by using the steel, DC motor with gearbox, electric linear actuator, two polyurethane wheels and two rubber wheels. The results of transporting up and down of seat base, the current, power, time and energy used in the electric linear actuator, will increase according to the load (10 kg - 100 kg), while electric linear actuator has to transport up or down. However, the average speed reduced due to the electric linear actuator has increase weight, resulting in the time of transportation of the seat base of the device increase. The results of transporting forward of the device with two-speed levels, the current, power, time and energy will increase according to the load while the device has to transport forward with high speed and low speed. The average speeds were reduced due to the device has increase weights. On the other hand, resulting in the time of transportation increases. Moreover, the result of the sound level while the device was transporting forward and backwards, it has sound to 55.3 dB, which was in the standard (not more than 60 dB). Also, the device had weighed 15.3 kilograms.

Keywords: *Leg weakness, Transporting, Device*

1. Introduction

Leg muscle weakness can occur with all genders and ages. It was caused by 1) nervous system disorder, 2) muscular system abnormalities, 3) leg muscles not being used, 4) immune disorders and 5) cardiovascular system (Kim, Ahn, Kwon, & Kim, 2011). Transferring is defined as moving a patient or elderly from one flat surface to another, such as from a bed to wheelchair, wheelchair to chair, and wheelchair to toilet, and vice versa (Pullen & Richard, 2008). Currently, the transport of the elderly and patient with leg muscles weakness as discussed above, using a transfer by caregiver and gait belt can help moving patients or elderly safer (Perry et al., 2018). Most problems are caused by standing up from the wheelchair and rotate the body to sit on the bed or sit on the flush toilet, or vice versa (Doyle, & McCutcheon, 2015). The patients have a chance to fall inside the home. The most frequent fall happens in bedrooms, kitchens and dining rooms, while few falls occur in the bathroom, on the stairs, or from ladders and step stools (Yoshida, 2007). Yoshihiro Kai (Kai., 2018) presented the walking support machine equipped with a lifting device. The designed machine is a passive-type machine with partial body weight support and prevents falling in the patient. The machine consists of only passive components while the lift device composed of a constant force spring and a powder brake. The spring with constant force was used for partial support of the bodyweight of the patient while powder brake was used to control the torque to prevent the patient's falling. Y. Nemoto et al. proposed the power-assisted walking support system for the elderly who need helping in standing up from the bed, sitting down to the toilet, walking around or rehabilitation on the bed (Nemoto et al., 2000). The system has two main basic features that are electrically power-assisted in both motions and the sensor system for easier motion instruction for the elderly. The research was tested and evaluated the system functions. The motion control method with force-sensitive has compensated for gravity on the slope also.

The researchers have an invention concept, that is, the elderly and patient support device with leg muscles weakness was used for transporting and preventing falls from a wheelchair, bed, and toilet, the elderly or patients do not have to stand and rotate the body to sit on a bed, wheelchair and flush toilet, or vice versa. This device was easy to use, strong, low cost, can be applied to the elderly, the disables, and some patients can be used to home and hospital.

2. Objective

This study focused on the design and construction of a movement support device for transporting the elderly or patients with leg muscles weakness between a wheelchair, bed, and toilet for home use, without standing up and rotate the body to sit on a bed, wheelchair or flush toilet and vice versa which was the prevention of falls.

3. Materials and Methods

3.1 Operating principle

The block diagram of a movement support device for transporting the elderly or patients with leg muscles weakness between a wheelchair, bed, and toilet was shown in Fig.1. The control switches (SW1 – SW3) were used to control the device operations. The microcontroller was the main component that controls all the operations such as h– bridge driver-1, DC motor, and gearbox, h– bridge driver-2, electric linear actuator, display, and alarm. The mechanical parts were used body support of the elderly or patients with leg muscles weakness, including transporting between a wheelchair, bed and toilet and vice versa.

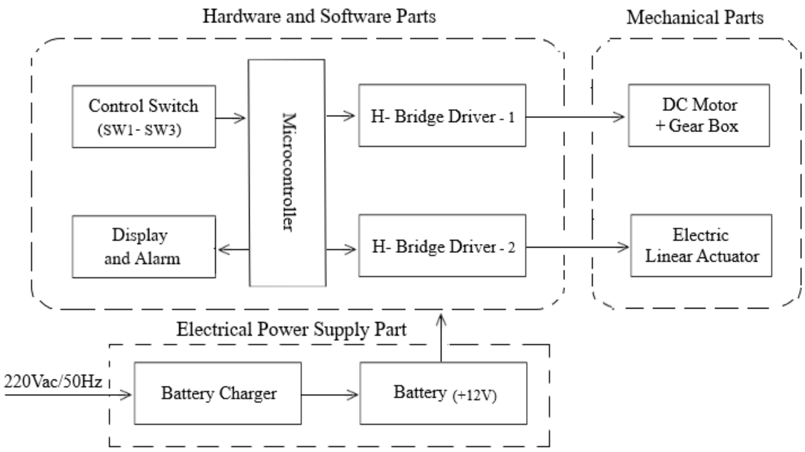

Figure 1 Block diagram of a movement support device for transporting the elderly or patients with leg muscles weakness between a wheelchair, bed and toilet and vice versa

3.2 Hardware and Software Parts

3.2.1 Hardware design

1) The control switch (SW1-SW3)

A control switch SW1 was used to set the two speeds (low and high) of DC motor which connected between the supply voltage (5V) and a microcontroller pin (22, 23). When this control switch has selected each speed level, it results to the microcontroller input was at a logical high level, the microcontroller will send a control signal (pin2) to the h-bridge driver-1, to supply direct current to the DC motor immediately. Therefore, the two speeds of DC motor depend on the setting control switch (SW1) as shown in Fig. 2.

A control switch SW2 was used to set the DC motor rotates clockwise or counterclockwise which connected between the supply voltage (5V) and a microcontroller pin (24, 25). When SW2 selected a pin 24 of the microcontroller, it sends a control signal (pin33) to the h-bridge driver-1 to supply electricity to the DC motor for clockwise rotation. On the other hand, when SW2 selected pin 25 of the microcontroller which sends a control signal (pin32) to the H-Bridge driver-1 so that supply electricity to the DC motor for rotation counterclockwise as shown in Fig. 2

A control switch SW3 was used to set the working electric linear actuator for pushrod extension and retraction, this SW3 connected between the supply voltage (5V) and a microcontroller pin (26, 27). When SW3 has selected to a pin 26 of the microcontroller which sends a control signal (pin31) to the h-bridge driver-2, to supply electricity to the electric linear actuator for pushrod extension. On the other hand when SW3 has selected to a pin 27 of the microcontroller which sends a control signal (pin30) to the h-bridge driver-2, so that supply electricity to the electric linear actuator for push rod retraction as shown in Fig. 2

2) Display and Alarm

When the device was moving forward or backwards, the microcontroller will send a control signal (pin28, 29) to the buzzer and LED (light-emitting diode) to generate a warning sound and flashing light respectively. To alert the elderly or patients to be aware of when the device was transporting, as shown in Fig. 2.

3) H- bridge driver-1 and H – bridge driver–2

The h-bridge driver-1 controls direct current supply from the battery to the DC motor; it can reverse the direct current to the DC motor in two directions by the microcontroller controlling, resulting in the DC motor rotating clockwise or counterclockwise. The h-bridge driver controls the direct current supply from battery to the electric linear actuator; it can reverse the direct current to the electric linear actuator in two directions by controlling of the microcontroller causes the electric linear actuator to operate, namely, pushrod extension and push rod retraction. We have chosen the h-bridge motor driver modules, 10 -30 V, 40 A to control the electricity to both DC motor and electric linear actuator. The advantages of it were small and the ability to control high power distribution as shown in Fig. 2

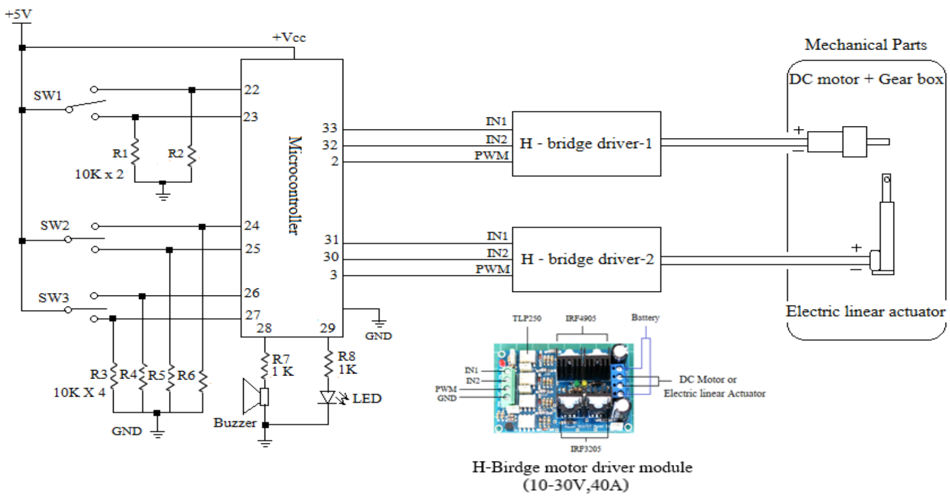

Figure 2 Interfacing of control switch (SW1 - SW3), display and alarm, h- bridge driver-1 and h – bridge driver – 2 with microcontroller

3.2.2 Software design

The software for control the operation of the device was programmed with C language by a flowchart, as shown in Fig.3.

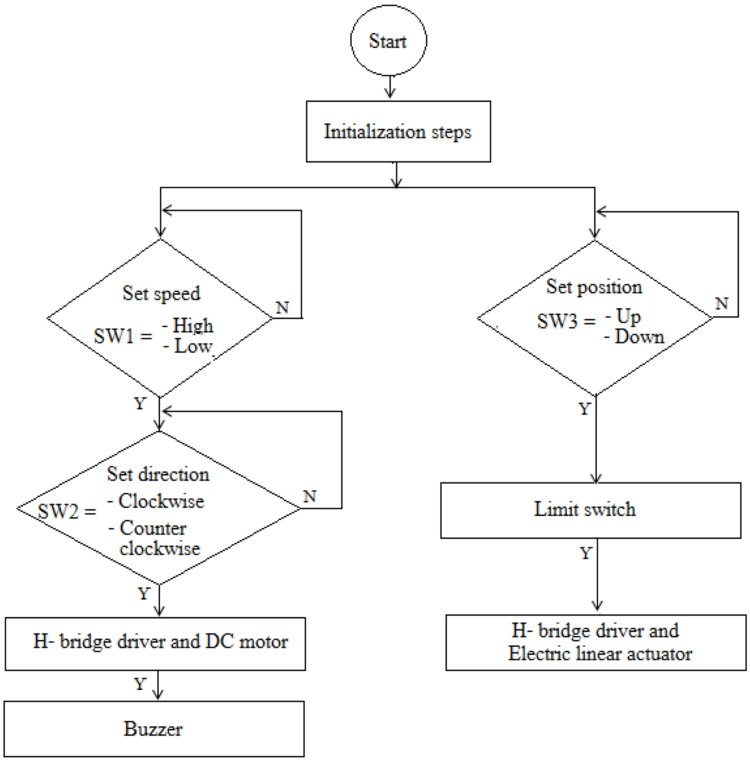

Figure 3 Main flow chart of the operating process

3.3 Electrical Power Supply Part

The battery was responsible for supplying current and voltage to each circuit of the device. We have chosen a 12V, 30Ah lithium-ion battery, the advantages of it was a small size, lightweight, enough electricity to work, and have a charger (model: LBC-H10980100W, input: 110 – 240Vac, 50/60Hz, 1.2 Amax and output: 12.6Vdc,5A). The characteristics of this battery, as shown in Fig. 4.

Figure 4 Characteristics of lithium-ion battery

3.4 Mechanical Parts

The mechanical parts composed of 3 main parts: 1) DC motor and gearbox used for drives the two wheels of a device to move forward or backwards. We have chosen an electric gear motor 12V (model N01007-10038), 60watt, low speed 100 RPM and 3/8" D shaft, the advantages of it was a small size, lightweight, high torque and consumes little power, 2) electric linear actuator was responsible for raising or lowering the seat base of a device. We have chosen an electric linear actuator 12Vdc, force 1300N and 16-inch stroke length and 3) machine structure was responsible for carrying the weight of patients or the elderly. It was made of thick steel and thin steel assembled, which include two small polyurethane wheels and two small rubber wheels, as shown in Fig. 5

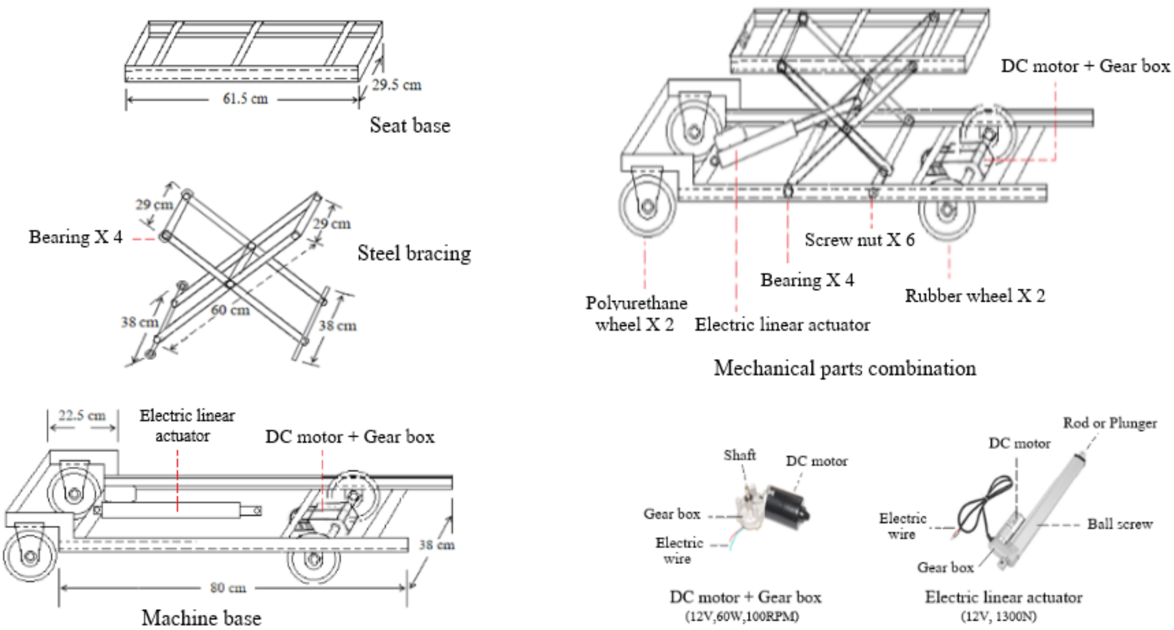

Figure 5 Characteristic of all mechanical parts

3.5 Device characteristics and components

Picture 6 showing a movement support device for transporting the elderly or patients with leg muscles weakness between a wheelchair, bed and toilet and vice versa, that it has been designed and built to complete as shown in Fig. 6

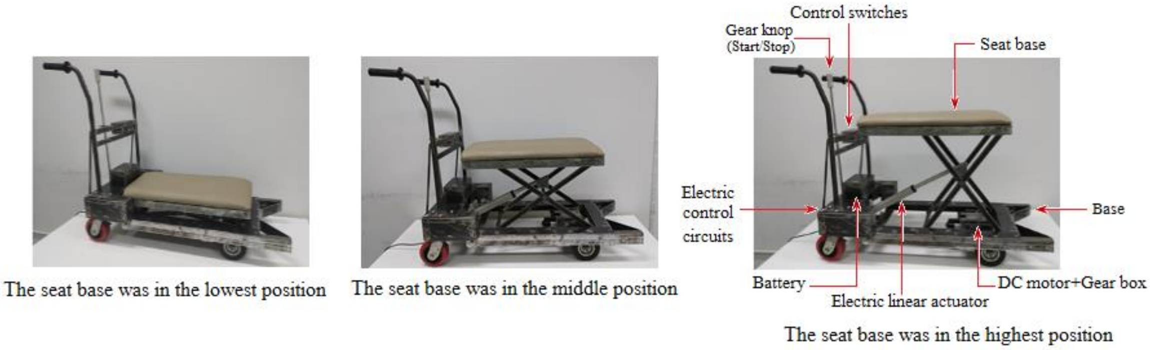

Figure 6 The completely designed a movement support device for transporting the elderly or patients with leg muscles weakness between a wheelchair, bed and toilet and vice versa

4. Results and Discussion

The results and discussion of design and construction a movement support device for transporting the elderly or patients with leg muscles weakness between a wheelchair, bed, and toilet was shown as follow:

1) This completely a movement support device shown in Fig.6. It was composed of 8 main parts: 1) electric linear actuator, 2) DC motor and gearbox, 3) base, 4) seat base, 5) electric control circuits and

control switches, 6) gear knop, 7) battery and 8) electric control circuits. This device had weighed to 5.5 kilograms.

2) The specification of a device used with a 12V, 30Ah lithium-ion battery power supply that has battery charger model LBC-H 10980100W. This device had three main parts of operating as follows: the first part was an adjustment of up and down the seat base, the electric linear actuator was used for up and down of the seat base, the second part was driving a device to move forward, or backward which used the DC motor and gearbox and the third part was gear knop used for setting the device to transporting forward, backwards or stop. The operation of this gear knop was related to a control switch SW2 which used to set the DC motor rotates clockwise or counterclockwise.

3) The testing results of the transporting up and down of seat base as follow: 1) the seat base has a transporting up, we have investigated the height of the bed, flush toilet seat and wheelchair seat. Found that it has a height from floor at 40 cm, 42 - 45 cm, and 45 - 50 cm, respectively. This research has determined the height of the device seat from the floor to 35 cm, which was the starting point of lifting weights (10 kg – 100 kg). The seat base of a device has to transport up from range 35 cm to 55 cm and transporting down from range 55 cm to 35 cm; it will cover with the height of a bed, flush toilet seat and wheelchair seat as mentioned above. Therefore, the seat base of a device will be transported up and down with a distance of 20 cm. We measured each value of electricity and time with a digital multimeter (Sanwa, RD701) and stopwatch (Casio, HS-30W) respectively. Furthermore, we have calculated electrical power, average speed and energy, as shown in Tables 1 and 2. The results from Tables 1 and 2 can be seen that the current (amps), power (watts), time (s) and energy (kJ) used in the electric linear actuator, it will increase according to the load (10 kg - 100 kg), while electric linear actuator has to transport up or down. However, the average speed (m/s) reduces due to the increased weight of the electric linear actuator, which results to an increase in time of transportation of the seat base of the device as well.

Table 1 Results of current, power, time, average speed and energy which was measured and calculated while the seat base of a device was transporting up.

Load Kg	**System Voltage V**	**Current amps**	**Power watts**	**Distances cm**	**Time s**	**Average speed cm/s**	**Energy kJ**
10	12	1.63	19.56	20	15	1.33	53.90
15	12	1.72	20.64	20	15	1.33	80.85
20	12	1.83	21.96	20	15	1.33	107.80
25	12	1.95	23.40	20	15	1.33	134.75
30	12	2.11	25.32	20	16	1.25	161.70
35	12	2.25	27.00	20	16	1.25	188.65
40	12	2.32	27.84	20	17	1.17	215.60
45	12	2.43	29.16	20	17	1.17	242.55
50	12	2.55	30.60	20	18	1.11	269.50
55	12	2.64	31.68	20	18	1.11	296.45
60	12	2.81	33.72	20	19	1.05	323.40
65	12	2.92	35.04	20	19	1.05	350.35
70	12	3.07	36.84	20	20	1.00	377.30
75	12	3.17	38.04	20	22	0.90	404.25
80	12	3.45	41.40	20	27	0.74	431.20
85	12	3.72	44.64	20	31	0.64	458.15
90	12	3.98	47.76	20	34	0.58	485.10
95	12	4.33	51.96	20	38	0.52	512.05
100	12	4.72	56.64	20	46	0.43	539.00

P = VI *P = power (watt),* *V = volt (v),* *I = current (amp.)*
Vave = s / t *Vave = average speed (m/s),* *s = distance (m),* *t = time (s)*
Ep = mgh *Ep = potential energy (kJ),* *m = mass (m),* *g = gravitational field strength (9.8),*
h = vertical height (m)

Table 2 Results of current, power, time, average speed and energy which was measured and calculated while the seat base of a device was transporting down

Load Kg	System Voltage V	Current amps	Power watts	Distances cm	Time s	Average speed cm/s	Energy kJ
10	12	0.76	9.12	20	12	1.61	34.30
15	12	0.82	9.84	20	13	1.56	51.45
20	12	0.78	9.36	20	13	1.53	68.60
25	12	0.86	10.32	20	13	1.52	85.75
30	12	1.02	12.24	20	13	1.50	102.90
35	12	1.09	13.08	20	13	1.49	120.05
40	12	1.15	13.8	20	14	1.48	137.20
45	12	1.19	14.28	20	14	1.44	154.35
50	12	1.23	14.76	20	14	1.44	171.50
55	12	1.27	15.24	20	14	1.39	188.65
60	12	1.42	17.04	20	15	1.37	205.80
65	12	1.50	18.00	20	15	1.36	222.95
70	12	1.73	20.76	20	15	1.34	240.10
75	12	1.81	21.72	20	15	1.32	257.25
80	12	1.96	23.52	20	15	1.30	274.40
85	12	2.10	25.2	20	16	1.28	291.55
90	12	2.38	28.56	20	16	1.25	308.70
95	12	2.41	28.92	20	16	1.22	325.85
100	12	2.53	30.36	20	17	1.19	343.00

4) The testing results of both transporting forward and backward of a device with two-speed levels as follow:

4.1) high and low speeds with transporting forward, we have adjusted the height of seat base to 45 cm from the floor (determined according to a height of the wheelchair's seat, which has a floor height of 45 cm), we put weights from 10 kg to 100 kg on the seat base of a device. After that, we set high and low speeds of a device to transporting direct way on a flat surface with a distance of 20 meters. We measured each value of electricity, time with a digital multimeter (Sanwa, RD701) and stopwatch (Casio, HS-30W). We calculated the electrical power, average speed, and energy which has the same method as for Table 1 and 2. Its results were shown in Table 3 and 4, respectively. The results of Table 3 and 4 show that the current (amps), power (watts), time (s) and energy (kJ) which will increase according to the load (10 kg - 100 kg), while a device has transporting forward with high speed (table 3) and low speed (table 4). The average speeds (m/s) were reduced due to a device has increase weight, resulting in an increase in time of transportation as well.

Table 3 Results of current, power, time, average speed and energy which was measured and calculated while a device was transporting forward on high speed.

Load Kg	Voltage System V	Current amps	Power watts	Distances m	Time s	Average speed m/s	Energy kJ
10	12	2.10	25.2	20	63	0.31	44.10
15	12	2.16	25.92	20	63	0.31	66.15
20	12	2.28	27.36	20	65	0.30	88.20
25	12	2.30	27.6	20	67	0.29	110.25
30	12	2.37	28.44	20	69	0.29	132.30
35	12	2.40	28.8	20	73	0.27	154.35
40	12	2.47	29.64	20	76	0.26	176.40
45	12	2.70	32.4	20	79	0.25	198.45

Load Kg	Voltage System V	Current amps	Power watts	Distances m	Time s	Average speed m/s	Energy kJ
50	12	2.76	33.12	20	81	0.24	220.50
55	12	2.83	33.96	20	84	0.23	242.55
60	12	2.93	35.16	20	87	0.23	264.60
65	12	2.95	35.4	20	90	0.22	286.65
70	12	3.11	37.32	20	94	0.21	308.70
75	12	3.32	39.84	20	97	0.20	330.75
80	12	3.55	42.6	20	99	0.20	352.80
85	12	3.64	43.68	20	109	0.18	374.85
90	12	3.72	44.64	20	111	0.18	396.90
95	12	3.82	45.84	20	118	0.16	418.95
100	12	4.22	50.64	20	121	0.16	441.00

Table 4 Results of current, power, time, average speed and energy which was measured and calculated while a device was transporting forward at a low speed.

Load Kg	Voltage System V	Current amps	Power watts	Distances m	Time s	Average speed m/s	Energy kJ
10	12	1.78	21.36	20	94	0.21	44.10
15	12	1.85	22.2	20	94	0.21	66.15
20	12	1.89	22.68	20	99	0.20	88.20
25	12	2.01	24.12	20	107	0.18	110.25
30	12	2.04	24.48	20	111	0.18	132.30
35	12	2.07	24.84	20	115	0.17	154.35
40	12	2.11	25.32	20	119	0.16	176.40
45	12	2.16	25.92	20	122	0.16	198.45
50	12	2.21	26.52	20	127	0.15	220.50
55	12	2.32	27.84	20	130	0.15	242.55
60	12	2.43	29.16	20	134	0.14	264.60
65	12	2.55	30.6	20	137	0.14	286.65
70	12	2.70	32.4	20	141	0.14	308.70
75	12	2.84	34.08	20	144	0.13	330.75
80	12	2.99	35.88	20	149	0.13	352.80
85	12	3.14	37.68	20	153	0.13	374.85
90	12	3.26	39.12	20	158	0.12	396.90
95	12	3.37	40.44	20	161	0.12	418.95
100	12	3.45	41.4	20	165	0.12	441.00

4.2) high and low speeds with transporting backwards. In this section, the researchers have determined that the device was transporting backwards at a distance of 20 meters. It is the testing process of high and low speeds with transporting forward and has the same results as in Tables 3 and 4 in all respects. Therefore, we do not report the results in this paper.

5. The testing result of the sound level while a device was transporting forward and backwards, it was verified value with Sound Level Meter model GM1356. Found that, it has sound to 55.3 dB which was in the standard (not more than 60 dB).

5. Conclusion

In this paper, the researchers focused on the design and construction of a movement support device for transporting the elderly or patients with leg muscles weakness between a wheelchair, bed, and toilet and vice versa for home use. This device was composed of 8 main parts: 1) electric linear actuator, 2) DC motor and gearbox, 3) base, 4) seat base, 5) control switches, 6) gear knop and 7) battery and charger and 8) electric control circuits. The operating of this a device has four main functions as follows, 1) a control switch (SW1) to set the speeds of the device (low and high), 2) a control switch (SW2) to order the device to move forward or backward, 3) a control switch (SW3) to set the working electric linear actuator to lift the seat base of the device to high or low levels, and 4) gear knop for setting the device to move forward, backward, or stop. The operation of the gear knop was related to a control switch SW2 which used to set the DC motor rotates clockwise or counterclockwise. The testing results of the device are following. First, the testing results of transporting up and down of seat base. From Tables 1 and 2, the current (amps), power (watts), time (s), and energy (kJ) used in the electric linear actuator will increase according to the load (10 kg - 100 kg), while electric linear actuator has to transport up or down. However, if the electric linear actuator has an increased weight, the average speed (m/s) will reduce, resulting in an increase in time of transportation of the seat base of the device. Secondly, the testing results of transporting forward of a device with two-speed levels. From Tables 3 and 4, the current (amps), power (watts), time (s), and energy (kJ) will increase according to the load (10 kg - 100 kg), while the device transports forward with high speed (Table 3) and low speed (Table 4). The average speeds (m/s) will reduce if the device has an increased weight, resulting in an increase in time of transportation. Lastly, the testing result of the sound level while a device was transporting forward and backwards, it has a sound of 55.3 dB, which was in the standard (not more than 60 dB). Also, the device weighed 15.3 kilograms.

6. Acknowledgements

Thank you to the research institute Rangsit University which provided funding for this research, thank you to College of Biomedical Engineering, Rangsit University for supporting and providing the facilities during the research and thank you to Orapin Jittawisuthikul, PT, Ph.D., the lecturer in the faculty of physical therapy, Rangsit University, she counseled and provided to academic knowledge of the process and methods for move patients or elderly with leg weak muscles between a wheelchair, bed, and toilet.

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