Design of 4-attachment Point Active Knee Exoskeleton for Sit to Stand Movement

Thunyaseth Sethaput, Pantakarn Somboon, Tnon Kaewphattharasathian, Than Angsakul, and Phattrarapol Teerapongpakdi
Department of Mechanical Engineering, Sirindhorn International Institute of Technology, Thammasat University, Pathum Thani, Thailand
Email: thunyaseth@siit.tu.ac.th, {6022800310, 6022791113, 6022781726, 6022791964}@g.siit.tu.ac.th

***Abstract*—This paper introduces the design principles for an active knee exoskeleton for sit to stand movement based on 4 attachments. Assistive devices enable people to regain their mobility, a critical function of human life. Many exoskeletons currently exist, however, most products assist in gait cycles of walking and running. Because the range of motion in these activities are relatively small and requires little torque, they're not suitable for activities such as sit to stand or stair climbing. The design presented aims to achieve 50% of the required torque for sit to stand movement for an 80 kg male. Comfort and safety are also important factors to maximize via mechanical design. In this paper, Arduino Mega 2560 board is employed to control the motion of the exoskeleton. The Arduino board serves as the microcontroller to control a stepper motor while logic gates and EMG sensors provide the input signal. The experimental results show significant decreases in metabolic metrics when using the exoskeleton, suggesting that the exoskeleton is successful in assisting the user.**

***Index Terms*— knee exoskeleton, active exoskeleton, sit to stand exoskeleton, EMG sensor exoskeleton, stepper motor exoskeleton, high torque exoskeleton**

I. INTRODUCTION

Mobility is vital for every human being, especially for the physically disabled. Technology plays an important role in this particular area which leads to the invention of various products including crutches, cane, walkers (rollators), wheelchair, and mobility assistive exoskeleton. Demand for mobility assistive exoskeleton is rising every year as a result. Unfortunately, body movements disorders continue to also rise rapidly across the globe, with the cause of severe symptoms such as multiple sclerosis, muscle weakness and strokes. Accelerating the growth of medical devices to support those patients with acceptable cost and ergonomics are the main criteria in this field.

Companies that have already invested heavily in this field include Ekso Bionics [1], Suit X (U.S. Bionics Inc.) [2], and ReWalk Robotics Ltd [3]. The Ekso GT Robotic Exoskeleton was designed for comprehensive gait therapy and as a tool to supplement professional physiotherapists. The Suit X PHOENIX was designed to help people with mobility disorders to be upright and mobile. ReWalk's exoskeleton was utilized a computer control system and motion sensors which it allows independent, controlled walking while mimicking the natural gait cycles of human walking. These exoskeletons are adequately suited for the goals they claim to achieve. However, their main purpose is not to specifically assist the sit to stand movement, but rather walking. Furthermore, they tend to cater towards people with severe cases of mobility disorders, such as paraplegic patients. Thus, they're too large, too heavy, and are overly complex for people who only require assistance the knees.

The objective of this paper is to present a design for an active exoskeleton specifically at the knees for assisting the user in standing up from a sitting position. This design is targeted not towards people with severe cases of mobility disorder, but to people that only experience muscle weaknesses at the knees, such as the elderly. Our contributions in this paper include: 1) a lightweight high torque transmission mechanism; 2) a joint design that reduces misalignment and maximizes comfort; 3) a mechanical safety feature for disengaging the actuator from the drive train. This design is intended to provide 40% to 60% assistive torque during the sit to stand movement.

II. DESIGN CRITERION

The exoskeleton must not only have the ability to provide sufficient assistance but must also be comfortable for the user. The device should seamlessly be integrated into regular daily activities. The design criterions are specified in Table I.

The first criteria involve range of motion. A typical range of motion for the movement of sitting down and standing up on a regular chair is around 95° for the average person [4]. The mechanical design will likely have a higher range of motion than 95° due to the nature of rotating joint design, which is critical because the user may wish to perform movements that require larger range of motion, such as in squatting down, which has a range of motion of 115°[4].

Second is the weight limitation. A heavy design will severely impact the mobility of users because it directly imposes external loads onto the user. After initially looking for parts and suitable materials to use, it's

Manuscript received June 8, 2021; revised August 21, 2021.

doi: 10.18178/ijmerr.10.12.676-682

decided that a reasonable weight limitation is 5 kg for one leg, including the battery because the user will have to carry around the battery as well. Most of the weight will be contributed by the motor and the battery, as we plan to use lighter materials for the frame.

Third is the limitation on the actual physical size of the device. Sagittal plane protrusion can be thought of as the thickness of the device when viewed from the frontal plane. If the device is too large, it may pose difficulty to the user when navigating through small spaces or sit in small chairs such as in airplanes. Because the torque required by the motor is fairly high, the motor will be expected to be very thick. Taking into account the transmission of gears and pulleys as well as machine elements such as bearings, screws, and washers, we've decided that the thickness should be less than 10 cm, as much as we would like it to be less.

Fourth is the torque required to back drive the device in the powered down state. If the user wishes to turn the device off or perhaps the battery supply diminishes, the user should be able to move the device passively with ease. One of the paper reviews state that they were able to achieve a back drivable torque of around 2 Nm [5]. However, they only achieved a torque of 16 Nm, which is considerably less than our goal. Therefore, our rough estimate is 5 Nm.

Fifth is maximum holding torque. According to one of the paper reviews, the maximum torque that is required during the sit to stand movement is around 0.8 Nm per kilogram of body weight per leg near the beginning of the ascending part of the movement [6]. Our goal is to provide around 40% - 60% of the torque requirements for an average 80 kg adult male. The simple calculation then results in a maximum holding torque of between 25.6 Nm and 38.2 Nm.

Sixth is knee joint misalignment. Misalignment between the knee joint and the exoskeleton joint induces undesired forces. During misalignment, the system becomes mechanically over constrained, causing undesired reaction forces at the brace to the leg. Although it's difficult to track and measure the misalignment, extensive efforts will be made to ensure that it is minimized.

The last criteria involve the time it takes for the device to complete the range of motion. The average healthy adult person takes less than 1 second to stand up. However, those who need the device may not require such rapid speed, so it has been decided that a completion of the movement within 5 seconds is adequate.

TABLE I. EXOSKELETON DESIGN CRITERION

Criteria	Numerical value
Range of motion	95 °
Weight (one leg + battery)	Less than 5 kg total
Sagittal plane protrusion	Less than 10 cm
Back drive torque	Less than 5 Nm
Maximum holding torque (per leg)	25.6 Nm - 38.2 Nm
Time to complete range of motion	5 seconds

III. FRAME

Since the upper frame supports components such as shafts, pulleys, gears, and motor, the material used is going to have to be relatively strong yet lightweight. For ease of manufacturing and cost consideration, aluminum is proposed as the material for the upper frame. Attached near the top of the upper leg of the frame is an acrylic rail for the motor to slide up and down. This mechanism allows the motor to be physically disconnected from the drive train, allowing the user the freedom to power off the device mechanically if they wish, in case of emergency situations where the motor refuses to turn off or when the motor is over-delivering power. A spring button system is installed to allow the user to release the motor via pressing a button instead of manually sliding the motor. This also stops the motor from involuntarily disconnecting from the drive train because the button acts as a locking mechanism.

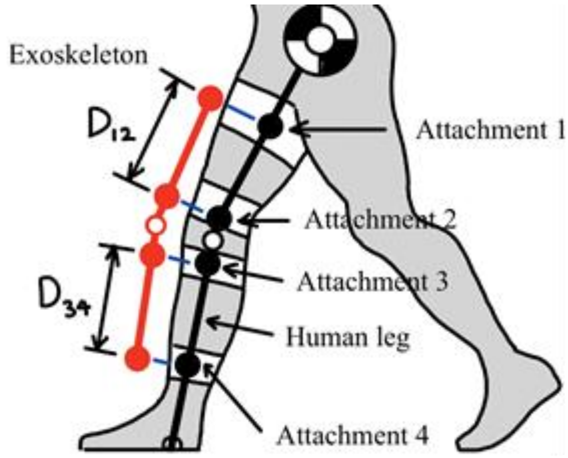

Figure 1. Knee exoskeleton attachment points. Figure modified from [5]

The braces transfer the torque from the exoskeleton to the body. The forces that the brace exert on the legs can be analyzed based on the configuration in Fig. 1 by drawing a free body diagram as illustrated in Fig. 2. The forces that the user feels are F_1, F_2, F_3, and F_4. N_x and N_y are reaction forces to the upper frame and the lower frame. T represents the torque generated at the knees by the exoskeleton. D_{12} represents the distance between the braces at the upper leg. Similarly, D_{34} represents the distance between the braces at the lower leg. Neglecting friction and small tangential forces and the weight of the exoskeleton, this model yields a consistent and overdetermined system with a unique solution. Equations (1) to (6) represent the static equations for force analysis of the exoskeleton frame. The solution reveals that under the same loading conditions (body-weight) and torque, the magnitude of forces F_1 and F_2 decrease as D_{12} increases. Similarly, the forces F_3 and F_4 decreases as D_{34} increases. This indicates that for a 4-contact point layout, the distances between the braces on both the thigh and calf should be maximum to reduce the pressure exerted on the legs. There are exoskeletons in the market using 2-contact point layout, one on the thigh and one on the calf.

The force analysis for this model is in fact, the same as the 4-contact point layout. The only difference is that D_{12} and D_{34} will be much less, therefore, applying excessively more pressure to the human leg in comparison. This implies that generally, an exoskeleton with a 4-contact point layout is more comfortable than a 2-contact point layout. Hence, the design in this paper utilizes the 4-contact point layout as shown in Fig. 3.

Assuming that N_x and N_y acts on the same points as F_2 and F_3 where θ is the angle that the link makes in relation to the vertical y axis;

$$- N_{2x} - F_1\cos(\theta) + F_2\cos(\theta) = 0 \quad (1)$$

$$N_{2y} - F_1\sin(\theta) + F_2\sin(\theta) = 0 \quad (2)$$

$$F_1 D_{12} = T_1 \quad (3)$$

$$N_{2x} - F_3\cos(\theta) + F_4\cos(\theta) = 0 \quad (4)$$

$$-N_{2y} - F_3\sin(\theta) + F_2\sin(\theta) = 0 \quad (5)$$

$$F_4 D_{34} = T_2 \quad (6)$$

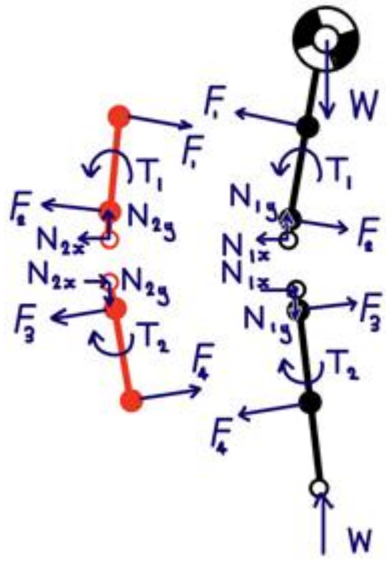

Figure 2. Force analysis of knee exoskeleton free body diagram. Figure modified from [5]

Most exoskeletons adopt a simple 1-DOF hinge joint at the knees, which induces misalignment between the human knee and the joint of the exoskeleton. This is because at the tibiofemoral joint, the tibia is a concave surface and the femur is a convex surface. During a long arc quad, the tibia moves on a stable femur. Therefore, the tibia is rolling and gliding in the same direction on the femur. Therefore, to reduce misalignment, a currently existing design proposes rolling knee joint where able to reduce knee misalignment to 15 mm and 8 mm at knee flexion angles of 120 °and 75 °respectively.

Figure 3. Prototype of the knee exoskeleton

IV. Drive Train

The NEMA 23 was chosen due to its relatively low price as well as high torque capabilities. The stepper motor is chosen instead of other types of motors because the user may want to hold their knees bent in some particular situations. Using a regular DC motor in this case would generate large amounts of heat which is a hazard to the user. The stepper is a very attractive choice because the position of the shaft can be controlled precisely which is critical when programming for the movement pattern in Arduino. The motor is capable of delivering 3 Nm of torque at holding.

Figure 4. Drive train

Referring to Fig. 4, the power from the motor gets transferred to the drive train via bevel gears. Only one set of gears is used in order to save the most amount of weight. The rest of the drive train is comprised of only aluminum pulleys. The pulleys are arranged in such a way that the relative velocity and displacement of the bar joint to the upper frame is the same as the relative velocity and displacement of the lower frame to the bar joint. This means that if the lower frame is rotated 90 °in relation to the upper frame, the angle between the bar joint and the upper frame will be 45 °, as shown in Fig. 5. The total train value is a ratio of 24:1. Assuming the motor can precisely output 3 Nm of torque, we can expect the exoskeleton to have a holding torque of 72 Nm. Apart from weight savings, the pulley further increases the back drivability of the drive train, since there is less friction loss in pulleys in comparison to gears. Additionally, less power will be lost to friction, therefore overall mechanical efficiency will be improved.

Figure 5. Bar linkage mechanism

V. Controls

The control in robotic exoskeletons was realized using kinematics commands or dynamics commands [7], [8]. Later, a new technology in control using neuro-muscular signals such as the electromyography (EMG) was implemented in several prototypes of robotic exoskeletons [8], [9], [10]. EMG sensors are now widely implemented in the field of robotics. The information obtained reflects the intensions of users.

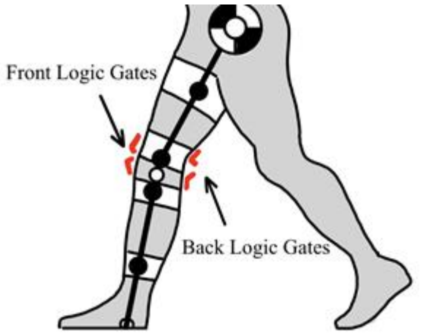

Figure 6. Logic gates placements. Figure modified from [5]

Referring to Fig. 6, two logic gates plate are attached on the upper frame as well as the lower frame of the exoskeleton, one on the front of the knee and one on the back for both the thigh and the calf. Signal will be sent between these plates when they are in contact where the input and outputs will be monitored by the Arduino board. At the sitting position, the back logic gates will connect, telling the controller to that the user is in the sitting position. The EMG sensor will detect muscle contraction from the biceps femoris, which, if matches specified conditions, will signal the Arduino board to signal the motor driver to actuate the motor and the user will begin standing up. The board will use signal processing to detect which stage of the movement of the user is in to determine the proper torque and speed to be used. Once the user is in the standing position, the frontal logic gates will connect and signal the motor to stop. The electronic hardware connections can be seen in Fig. 7.

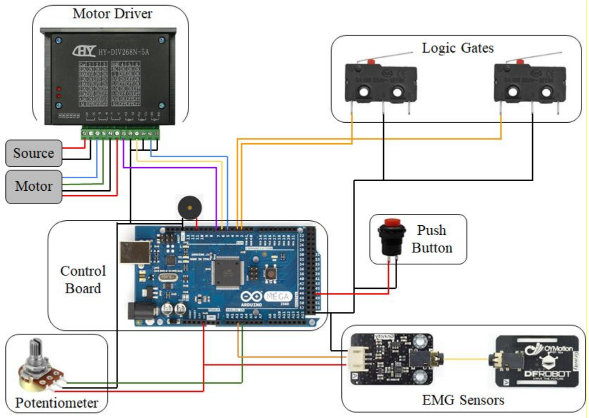

Figure 7. Electronic hardware architecture

VI. Experimental Results

Exercise and training promote acute increases in heart rate as well as blood pressure [11]. It has been demonstrated that increases in these 2 parameters become even more apparent as the intensity and duration of exercise increases. Thus, if the exoskeleton is able to assist the user, it should reduce the intensity of the exercises. Therefore, the exoskeleton's effectiveness will be evaluated by the degree to which it reduces the increase in heart rate and blood pressure during exercising.

The experiments were conducted with 7 healthy young individuals. For both experiments, the participants will sit down and rest for 5 minutes before the first test begins. The participants will start off by squatting their body weight for 12 repetitions on one leg without assistance (not wearing) from the exoskeleton. Both the descending and the ascending portion will be timed to 5 seconds because the exoskeleton requires that specific amount of time as well. Both the heart rate and the blood pressure will be measured exactly before the first repetition is completed. After 12 repetitions have been completed, the heart rate and the blood pressure will be measured. The participant will rest for 5 minutes before completing the same test but with the exoskeleton assistance.

Each participant repeated the experiment 5 times to find the average for each parameter. The experiment was conducted in a room controlled at 25 degrees Celsius so that variation in ambient temperature does not affect the results. The participant performed the test without assistance to avoid data biases because such argument can be made that the test without exoskeleton assistance had higher heart rate because the participants were pre-exhausted from the test with the assistance.

Results show that on average, the nominal heart rate was increased from 75.00 BPM to 107.57 BPM during the test without assistance from exoskeleton as shown in Table II. However, the test with assistance from the exoskeleton only showed an increase from 77.43 BPM to 82.43 BPM on average as shown in Table III. Referring to Table IV, the results for the blood pressure measure show that the systolic blood pressure increase for the test without the exoskeleton went from 115.57 mmHg on average to 135.86 mmHg. For the test with exoskeleton assistance, the systolic blood pressure increase was from 115.00 mmHg to 127.29 mmHg as illustrated in Table V.

TABLE II. RESULTS OF HEART RATE TEST WITHOUT ASSISTANCE

Number of test subject	Without device	
	Nominal Heart Rate (BPM)	Heart Rate after test (BPM)
1	77	117
2	74	98
3	74	88
4	76	133
5	71	91
6	75	104
7	78	122
Average	75.00	107.57

TABLE III. RESULTS OF HEART RATE TEST WITH ASSISTANCE

Number of test subject	With device	
	Nominal Heart Rate (BPM)	Heart Rate after test (BPM)
1	73	94
2	79	61
3	79	84
4	79	91
5	77	76
6	74	82
7	81	89
Average	77.43	82.43

TABLE IV. RESULTS OF BLOOD PRESSURE TEST WITHOUT ASSISTANCE

Number of test subject	Without device	
	Nominal Blood pressure (mmHg)	Blood pressure after test (mmHg)
1	128/76	157/87
2	117/70	139/67
3	114/75	117/80
4	112/79	128/74
5	115/76	146/82
6	109/75	141/79
7	114/73	123/77
Average	115.57/74.86	135.86/78.00

TABLE V. RESULTS OF BLOOD PRESSURE TEST WITH ASSISTANCE

Number of test subject	With device	
	Nominal Blood pressure (mmHg)	Blood pressure after test (mmHg)
1	131/77	151/83
2	105/61	131/67
3	110/75	115/76
4	115/78	117/74
5	119/75	115/73
6	108/78	125/81
7	117/67	137/76
Average	115.00/73.00	127.29/75.71

To test the exoskeleton’s assistance in reducing metabolic fatigue, a maximum repetition test was conducted as well. The test consists of the test subjects performing single-leg sit to stand motion from a chair for the greatest number of repetitions the subject is capable of performing according to the fitness of the test subjects within 120 seconds. The subjects performed each repetition consecutively without any rest in between each repetition and was controlled spend 5 seconds to both stand up and sit down for both unassisted and assisted tests. Thus, if the test subjects are able to perform a greater number of repetitions with the assistance of the exoskeleton, the exoskeleton would be successful in reducing metabolic fatigue for the user.

The experiment was first conducted without exoskeleton assistance and then with assistance for the same reason as the first test. Using the same test subjects and ambient condition as the first experiment, the subject performed the second test on the day after the first test so that the test subject can fully rest for 24 hours between tests.

Referring to Table VI. the results showed that on average the subjects were able to perform 7.43 repetitions without the device and 12.29 repetitions with the device.

TABLE VI. RESULTS OF MAXIMUM REPETITION TEST

Number of test subject	Without device	With device
1	6	10
2	8	14
3	5	8
4	11	16
5	8	15
6	5	9
7	9	14
Average	7.43	12.29

VII. Discussion and Conclusion

Experimental results in Table II and Table III show that the average percentage increase in heart rate after the test in relation to nominal heart rate without assistance is 43.4%. In comparison, the average percentage increase in heart rate with exoskeleton assistance is 6.5%. This means that the exoskeleton successfully managed to reduce the increase in heart rate by 36.9%. Furthermore, all participants experienced a lower heart rate with the exoskeleton after the test compared to the heart rate without the test. In fact, participant 2 and 5 actually experienced a decrease in heart rate after the test with the exoskeleton, which could be from measurement errors.

Additionally, in Table IV and Table V, the average percentage increase in systolic blood pressure after the test in relation to nominal systolic blood pressure without assistance is 17.6%. In comparison, the average percentage increase in systolic blood pressure with exoskeleton assistance is 10.7%. This means that the exoskeleton successfully managed to reduce the increase in systolic blood pressure increase by 6.9%. Unlike the heart rate results, not all participants experienced a lower increase in systolic blood pressure with the exoskeleton after the test compared to the increase in systolic blood pressure without the exoskeleton. Participant 2, 3, and 7 experienced higher systolic blood pressure increases with the exoskeleton. This could be because the participants were feeling excited or scared when using the exoskeleton, which could lead to spikes in systolic blood pressure. Diastolic pressure appears not have not been affected before and after the test as well as with and without exoskeleton assistance, since the standard deviation amongst changes in diastolic blood pressure for all tests is only 5.34 mmHg, too insignificant to draw any conclusions.

Finally, in Table VI, it is shown that the test subjects were able to perform 65.41% more repetitions on average by using assistance from the exoskeleton compared to not using assistance.

These results suggest that the exoskeleton was successful in reducing the intensity of the sit to stand exercise as well as in reducing the metabolic fatigue. The exoskeleton has the potential to be programmed for the walking gait as well to assist more than one movement by modifying the control system as in the electrical and the code. The transmission design ensures that the exoskeleton can provide adequate amount of torque while still being back drivable by the use of pulleys. It is planned to further reduce the weight of the system by utilizing carbon fiber composites instead of aluminum as structural materials as well as reduce the thickness of the pulley system for improved ergonomics.

However, there are still slight discomfort near the knees when wearing the device, particularly because the exoskeleton will shift towards the ground when the user is standing due to the relatively heavy weight of the device. Using the shoulder harness mitigates this issue by pulling the device upward, supported by the shoulders. Although, this will cause slight discomfort in the shoulders. In future designs, it is planned to replace the shoulder harness with a waist belt instead to determine which support method is more comfortable for the user.

Conflict of Interest

The authors declare no conflict of interest.

Author Contributions

All authors carried out the literature survey, kinematic designed of exoskeleton mechanism, conducted the experiments and analyzed the data. T.S. conceived of the presented idea, directed the project, and revised the manuscript. T.S. and P.S. devised the project. P.S. drafted the manuscript with input from all authors and designed the motor and batteries. T.K., T.A. and P.T. designed and fabricated the frame. T.K. introduced the spring button mechanism. T.A. and P.T. designed and fabricated the control system. All authors had approved the final version of the manuscript.

Acknowledgment

We want to express our gratitude towards Dr. Maroay Phlernjai for advising the use of the bar linkage mechanism as well as advising the mechanical design overall while recommending the stepper motor used for this project.

We would also like to thank Mr. Manit Paisansopon for assisting in wiring the electrical parts, providing a DC power source for the exoskeleton to be tested, and recommending the batteries to use to power the exoskeleton.

Finally, we would like to thank Mr. Pantakarn's grandfather and aunt for providing us a facility to manufacture the parts and for arranging the logistics of ordering parts from external suppliers.

References

[1] A. Voilqué, J. Masood, J. Fauroux, L. Sabourin, and O. Guezet, "Industrial exoskeleton technology: Classification, structural analysis, and structural complexity indicator," in *Proc. Wearable Robotics Ass. Conf.*, pp. 13-20, Mar. 2019.

[2] C. B. Baunsgaard, U. V. Nissen, A. K. Brust, A. Frotzler, C. Ribeill, Y.-B. Kalke, and F. Biering-Sørensen, "Gait training after spinal cord injury: Safety, feasibility and gait function following 8 weeks of training with the exoskeletons from Ekso Bionics," *Spinal Cord*, vol. 56, no. 2, pp. 110-116, Feb. 2018.

[3] A. Esquenazi, M. Talaty, A. Packel, and M. Saulino, "The ReWalk powered exoskeleton to restore ambulatory function to individuals with thoracic-level motor-complete spinal cord injury," *American Journal of Physical Medicine & Rehabilitation*, vol. 91, no. 11, pp. 911-921, Nov. 2012.

[4] H. J. Kim, J. Noh, and W. Yang, "Knee-assistive robotic exoskeleton (KARE-1) using a conditionally singular mechanism for industrial field applications," *Applied Sciences*, vol. 10, no. 15, p. 5141, July. 2020.

[5] J. Wang, X. Li, T. H. Huang, S. Yu, Y. Li, T. Chen, A. Carriero, M. Oh-Park, and H. Su, "Comfort-centered design of a lightweight and backdrivable knee exoskeleton," *IEEE Robotics and Automation Letters*, vol. 3, no. 4, pp. 4265-4272, Oct. 2018.

[6] M. Roebroeck, G. Lankhorst, C. Doorenbosch, J. Harlaar, and R. Jacobs, "Biomechanics and muscular activity during sit-to-stand transfer," *Clinical Biomechanics*, vol. 9, no. 4, pp. 235–244, July 1994

[7] N. G. Tsagarakis and D. G. Caldwell, "Development and control of a "soft-actuated" exoskeleton for use in physiotherapy and training," *Autonomous Robots*, vol. 15, pp. 21-33, July 2003.
[8] E. Rocon, A. F. Ruiz, J. L. Pons, J. M. Belda-Lois, and J. J. Sanchez-Lacuesta, "Rehabilitation robotics: A wearable exo-skeleton for tremor assessment and suppression," in *Proc. IEEE International Conference on Robotics and Automation*, pp. 2271-2276, Apr. 2005.
[9] K. Kiguchi and T. Fukuda, "A 3 DOF exoskeleton for upper limb motion assist: consideration of the effect of bi-articular muscles," in *Proc. IEEE International Conference on Robotics and Automation*, vol. 3, pp. 2424-2429, Apr.-May 2004.
[10] J. Rosen, M. Brand, M. Fuchs, and M. Arcan, "A myosignal-based powered exoskeleton system," *IEEE Transaction on Systems, Man and Cybernetics - Part A: Systems and Humans*, vol. 31, no. 3, pp. 210-222, May 2001.
[11] M. J. Duncan, S. L. Birch, and S. W. Oxford, "The effect of exercise intensity on postresistance exercise hypotension in trained men," *Strength and Conditioning Research*, vol. 28, no. 6, pp. 1706–1713, June 2014.

Thunyaseth Sethaput received his B.S. degree in mechanical engineering from Sirindhorn International Institute of Technology, Thammasat University, Thailand and Ph.D. in systems and control engineering, from Case Western Reserve University, Ohio, USA. He is an assistant professor and chairperson of mechanical engineering program at Sirindhorn International Institute of Technology, Thailand. His research interests are control system, systems biology, biomedical mechanics, simulation modeling, finite element analysis and computational fluid dynamics.

Pantakarn Somboon received his bachelor's degree in mechanical engineering from Sirindhorn International Institute of Technology, Thammasat University, Thailand in 2021. He has worked as an intern at Chevron Thailand Exploration and Production in 2020 and joined Weatherford International Ltd. in 2021.

Tnon Kaewphattharasathian received his bachelor's degree in mechanical engineering from Sirindhorn International Institute of Technology, Thammasat University, Thailand in 2021. His research in bachelor's degree was sit-to-stand assistive exoskeleton specifically on mechanical frame design.

Than Angsakul received his bachelor's degree in mechanical engineering from Sirindhorn International Institute of Technology, Thailand in 2021. He is applying for the Master of Science in Finance and Investment at Durham University Business School in the academic year 2022.

Phattrarapol Teerapongpakdi graduated from Sirindhorn International Institute of Technology with a bachelor's degree in mechanical engineering in 2021. Currently applying master's degree in renewable energy engineering at Curtin University.