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Segmented Bending Soft Actuator for Enhanced Finger Flexion in Rehabilitation Glove

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Abstract: Rehabilitation devices like assistive gloves require bending-type soft actuators for controlled, repetitive finger movements essential for therapy. However, non-segmented actuators often struggle to replicate natural finger articulation, which can cause discomfort and reduce patient compliance. This paper presents the design and assembly of a segmented bending pneumatic soft actuator to achieve index finger flexion, aiming to improve comfort and support natural finger movement at low pressure. The actuator is integrated into a glove with a flexible bend sensor to measure the flexion angle of the metacarpophalangeal joint. Ecoflex 0-50 A-B silicone rubber is used in the fabrication, with air bubbles removed to ensure consistent actuator performance. The study investigates the actuator's performance and the sensor's ability to accurately measure joint flexion. The results, presented through detailed graphs, analyze the actuator’s flexibility, bending, and elongation under different pressure scenarios, offering insights into its effectiveness in improving patient comfort, joint articulation, and rehabilitation outcomes.

Keywords: Assistive Glove, Finger flexion, Flexible Bend Sensor, Segmented Bending Actuator

1 Introduction

STROKE is a leading cause of death and a primary contributor to adult-onset disability worldwide, with finger flexor spasticity being a common and debilitating symptom [1]. Conventional rehabilitation techniques, such as repetitive physical therapy sessions in specialized clinics, encounter obstacles like patient motivation, limited access to healthcare professionals, and high costs. In response to these challenges, there is an increasing demand for devices that facilitate rehabilitation outside of medical centers, thereby reducing reliance on healthcare professionals.

Robotic systems designed to control hand and finger movements during rehabilitation exercises often incorporate motors, which present several challenges. The size and weight of these motors may compromise usability and comfort, particularly for delicate finger-related tasks. Furthermore, the bulkiness and high-power consumption of motor-driven systems restricts their portability, an important factor in medical settings. The complex control systems in these robotic systems may also introduce technical challenges that affect ease of use. Additionally, the rigid nature of motor-driven systems may limit their adaptability to individual patient needs, potentially reducing the effectiveness of rehabilitation efforts and the overall user experience.

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As an alternative to address the limitations of motor-driven rehabilitation devices, the field of soft robotics has expanded significantly in recent years, especially in designing advanced, wearable robotic hands. These aim to address hyperexcitability of the finger flexor muscles and improve hand functionality for rehabilitation and assistance [2]-[6]. Recent studies have focused on developing soft robotic rehabilitation gloves that can offer personalized, home-based support and training for stroke patients [7]-[12].

Soft actuators offer several advantages, including the ability to safely interact with the patient's hand, provide customized forces and motions tailored to individual needs, and replicate complex hand movements. The drawbacks of curved bending actuators include users experiencing discomfort at the sharp contact points as well as limited flexibility at the finger joints [13]-[14]. Utilization of curved bending actuators with limited compliance may result in a lack of patient's motivation, potentially hindering the effectiveness of rehabilitation exercises.

Therefore, some research on segmented bending actuator designs has been conducted to address these limitations [9]-[10], [15]-[19]. However, improving the performance, and customizability of soft actuators for rehabilitation applications remains a critical area of focus. Additionally, these rehabilitation gloves often lack the ability to provide real-time feedback on the flexion angle of the user's fingers, which could be a valuable feature to integrate. To address these challenges, this study proposes the design and development of a segmented pneumatic soft actuator for enhanced finger flexion in a rehabilitation glove with metacarpophalangeal (MCP) joint's bending angle feedback.

2 Methodology

2.1 Segmented Bending Actuator Design

The key system components depicted in the block diagram in Fig.1 comprise an air pump that pressurizes air for the actuator, an air pressure regulator that controls the pneumatic input from the air pump to the actuator, and a segmented bending actuator that generates segmented bending motion to enable finger flexion. The air pump, which powers the actuator, operates at varying pressures from 0 kPa to 40 kPa, with increments of 2 kPa.

Additionally, a 1-axis flexible sensor, the BendLabs sensor developed by Nitto Bend Technologies was installed on the glove as shown in Fig. 2 which worn by user to provide real-time feedback on the finger's MCP flexion angle. This sensor integration enabled close observation of the actuator's performance in relation to the assisted finger joint flexion.

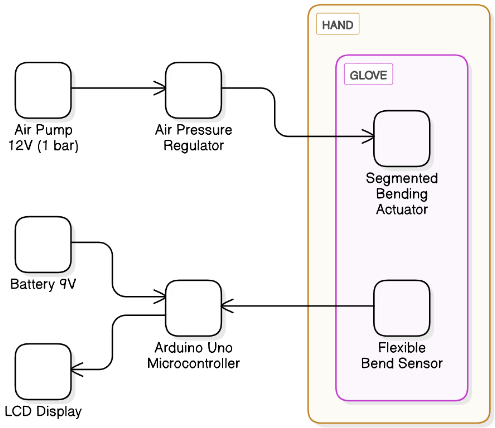


Fig 1. System block diagram.

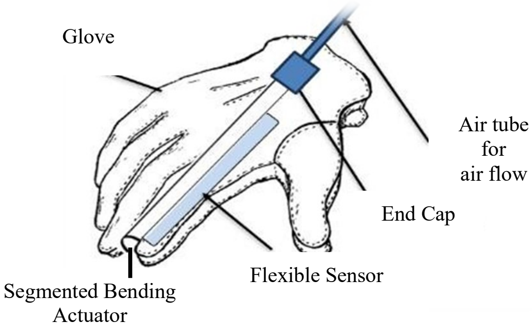


Fig 2. Sensor and actuator placement.

The development of effective soft actuators necessitates a careful consideration of the unique anatomical features of the intended users. To this end, a comprehensive assessment of finger dimensions was conducted to ensure that each soft actuator was specifically tailored to match the individual finger lengths of the participants. This analysis went beyond simply measuring the overall finger length and instead focused on the specific articulation points along the finger. As shown in Fig. 3 and Fig. 4, the length from the base of the finger to the MCP joint, from the MCP to the PIP joint, and from the PIP to the DIP joint were meticulously measured. These detailed measurements were conducted to aid in actuator design, ensuring that specific sections induce bending while others allow extension, thereby generating segmented bending that closely emulates the complexities of human finger biomechanics.

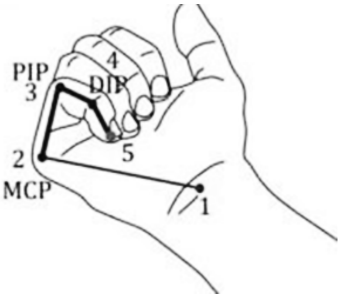
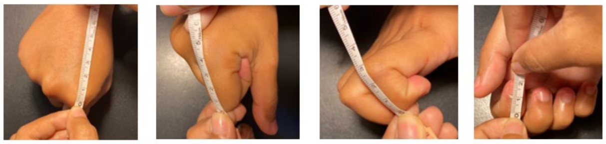


Fig 3. Finger joint representation.



(a) (b) (c) (d)

Fig 4. Finger measurement setup (a) from wrist to MCP joint (b) from MCP joint to PIP joint (c) from PIP to DIP joint and (d) from DIP joint to fingertip.

The segmented bending actuator features a total length of 160 mm, comprising a core segment of 140 mm and fixed-length end caps of 10 mm each. This overall dimension corresponds to the mean index finger length observed across a sample of six individuals. The participants were female, between 20-22 years old, and right-handed. Their hand size was suitable for the glove used in the study.

A half-cylinder actuator design is introduced, enabling the actuator to be steadily positioned on its flat surface above the finger. Fabrication of the actuator necessitates the design of molds for both the inner and outer rubber layers using SolidWorks software. The half-cylinder actuator mold assembly consists of seven distinct components, as depicted in Fig. 5 and Fig. 6. This includes two engraved fiber pattern molds (A1 and A2) for fabricating the inner rubber layer, two outer molds (B1 and B2) for the outer rubber layer, a 10 mm half-cylinder rod, mold A3 to create the half-cylinder hollow structure in the middle for the actuator body, a half-cylinder rod holder, mold A4 to position the rod at the center of the actuator's structure and ensure a consistent rubber layer thickness throughout the fabrication process, and end cap molds C1 and C2 for the end caps that connect the actuator body to the air tube.

The other end cap, without an air tube connection, was also fabricated using C1 and C2 molds. However, a tube was not incorporated to create an air flow path, as it is designed to be solid. With this solid end cap in place, the assembly is complete. The mold designs were manufactured through 3D printing and subsequently utilized to fabricate the segmented bending soft actuator, as depicted in the step-by-step illustration in Fig. 7.

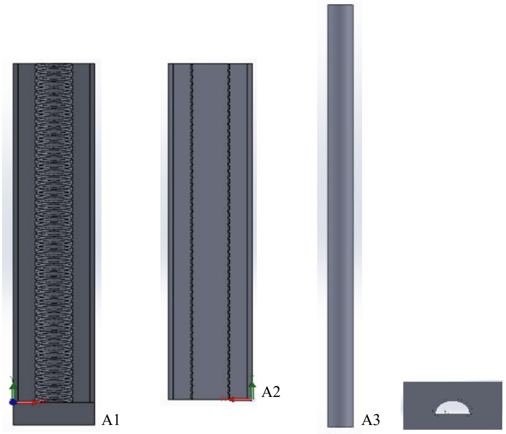


Fig 5. Top view of molds design of inner rubber layer, rod and holder.

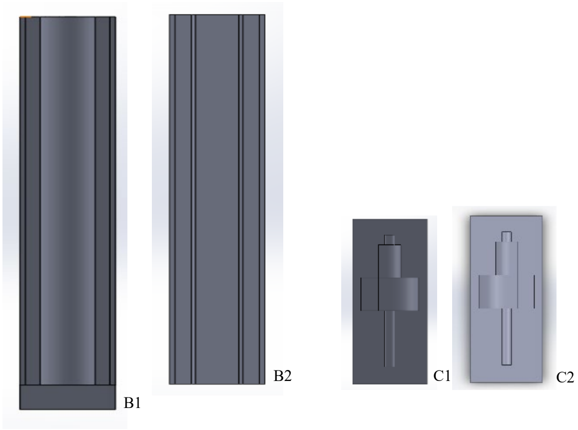


Fig 6. Top view of molds design of outer rubber layer and end cap.

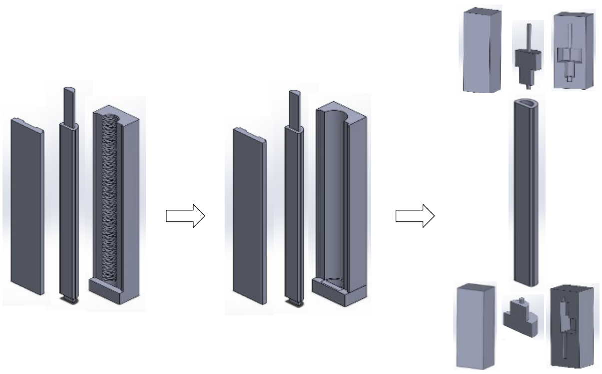


Fig 7. 3D view mold design of segmented bending actuator.

2.2 Fabrication Process of Segmented Bending Actuator

The fabrication process for the inner and outer rubber parts of the segmented bending actuator involves a series of meticulous steps, as depicted in Fig. 8. In line with the provided guidelines, a 1:1 mixture of Ecoflex 0-50 A-B silicone rubber was subjected to a 3-minute vacuum treatment to eliminate any air bubbles. The silicone rubber compound was then carefully poured into the engraved fiber pattern molds within a controlled, clean environment. This was followed by additional vacuum processing to remove any residual air bubbles, as the engraved sections of the mold were prone to creating pockets where air could become trapped. After a 40-minute solidification period in an oven at 40-degree Celsius, the core inner rubber structure was fabricated. At this stage, the actuator's rod remained unassembled.

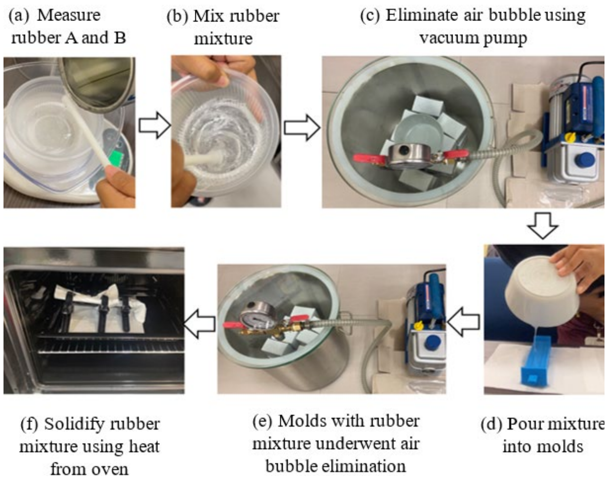


Fig 8. Inner and outer rubber layer fabrication process.

After establishing the core inner rubber, a strain-limiting layer and fiber reinforcements are applied to the solidified core inner rubber, enabling both bending and extending functionalities. Woven fiberglass serves as the strain-limiting layer, allowing specific sections which are diagonally shaded as illustrated in Fig. 9 to bend. Four sections of Fig.9 are extension segments, while three sections are bend segments. The fiber layer is interlaced in a specific pattern, in this case, a braided configuration of 81-degree angle at the cylindrical part of the actuator and 90-degree angle at the flat part of the actuator.

Upon completion of the fiber reinforcement, an additional outer rubber layer is fabricated using the same process depicted in Fig. 8. The overall production process is illustrated in Fig. 10. Following the removal of the central rod, rubber end caps are fabricated using a 4 mm diameter tube, enabling air inlet and outlet, as shown in Fig. 11. Finally, the three distinct components - the actuator body and the two end caps are integrated, and the connected regions undergo additional rubber processing to establish a strong bond, culminating the actuator manufacturing.

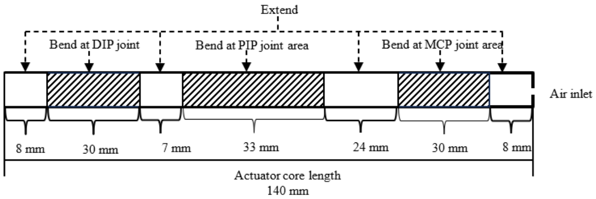


Fig 9. Bending segment achieved by addition of strain limiting layer at the flat part of fiber reinforcement (diagonally shaded), and extension segment (without shade) alternating to yield segmented bending motion.

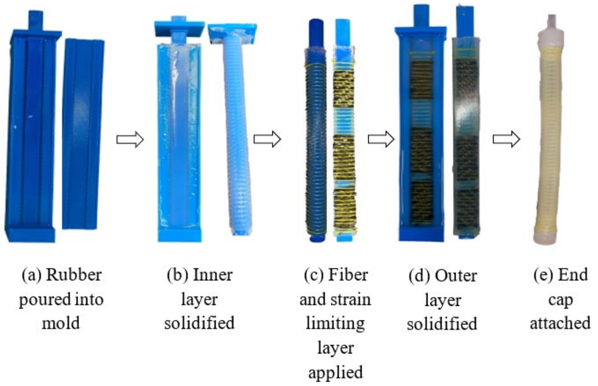


Fig 10. Segmented bending actuator body fabrication steps.

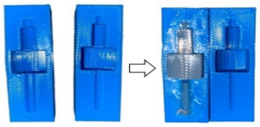


Fig 11. Actuator's end cap molds.

2.3 Glove and Sensor Attachment Design

The design of the segmented bending actuator's glove and component attachment, depicted in Fig. 12, utilizes a non-slip glove as the foundation.

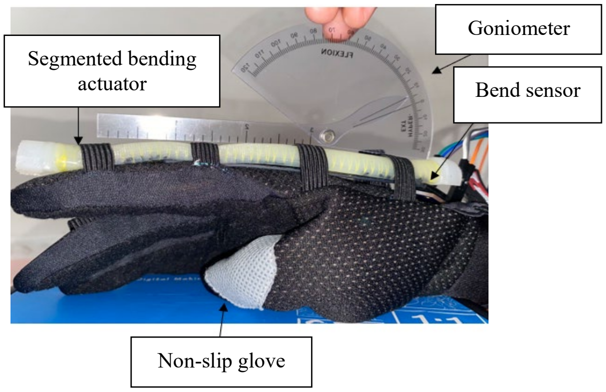


Fig 12. Glove and component attachment design.

A flex sensor from Nitto Bend Technologies is strategically positioned such that the center point of the sensor corresponds to the MCP joint, with the actuator situated directly above the sensor to form the structural ensemble. This arrangement ensures accurate and reliable data acquisition, enabling the sensor to capture measurements aligned with the natural finger motions during rehabilitation. Obtaining reliable data is crucial for effective performance evaluation and customized therapeutic interventions

3 Results and Discussion

3.1 Segmented Bending Actuator Displacement

To ensure the reliability and consistency of the observed performance trends, the experiment was conducted three times. The bending motion of the segmented bending actuator is shown in Fig. 13. The outcomes from these measurements are thoroughly presented in Table 1. The collected data consistently showed a positive correlation between pressure and elongation length. This relationship is clearly depicted in the graphical representations of the data in Fig. 14, illustrating that higher pressure levels are associated with increased elongation lengths.

Fig 13. Segmented bending actuator motion in response to every 10 kPa incremental input pressure.

The segmented bending actuator exhibited elongation ranging from 62 mm to 65 mm across three trials conducted at 40 kPa of air pressure. Given the baseline length of 160 mm, the total extension achieved was between 222 mm and 225 mm. The actuator's ability to elongate allows it to closely replicate the natural motion of finger extension and flexion. This enhanced actuator design allows for increased range of motion, enabling more comprehensive and naturalistic finger articulation, thereby expanding the potential utility of the actuator for rehabilitation purposes.

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Table 1. Measurement of actuator elongation length.

Pressure (kPa)	Elongation length (mm)		
	1st trial	2nd trial	3rd trial
0	0	0	0
2	3	2	3
4	5	4	4
6	7	7	7
8	8	8	9
10	10	9	10
12	13	11	11
14	16	13	15
16	20	15	17
18	23	20	20
20	25	23	23
22	28	25	25
24	30	28	30
26	32	32	33
28	34	35	35
30	40	42	40
32	42	45	42
34	46	49	46
36	51	54	53
38	55	55	55
40	63	65	62
30	40	42	40
32	42	45	42
34	46	49	46
36	51	54	53
38	55	55	55
40	63	65	62

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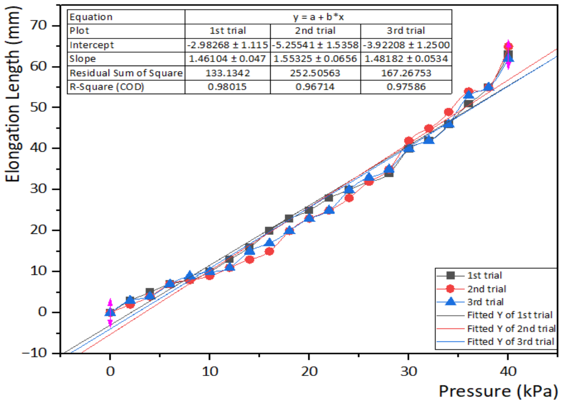
The reliability and consistency of the observed elongation length trends have been confirmed through statistical analyses and repeated data collection. The high R-squared value of approximately 0.98 indicates a very strong linear correlation between pressure and elongation length. This implies that the elongation length of the actuator can be predicted with a high degree of accuracy based on the applied pressure. This finding is crucial for applications necessitating precise control of elongation. The dashed black line represents the best-fit line, illustrating the overall trend across all trials.



Equation	y = a + b*x		
Plot	1st trial	2nd trial	3rd trial
Intercept	-2.98268 ± 1.115	-5.25541 ± 1.5358	-3.92208 ± 1.2500
Slope	1.46104 ± 0.047	1.55325 ± 0.0656	1.48182 ± 0.0534
Residual Sum of Square	133.1342	252.50563	167.26753
R-Square (COD)	0.98015	0.96714	0.97586

Fig 14. Elongation length versus input pressure with R-squared: 0.98.

3.2 MCP Finger Joint Flexion Angle Measurement

The graph in Fig. 15 shows a comparison between Goniometer and BendLabs flex sensor measurements of MCP angle versus input pressure, with both methods showing a positive linear correlation. The collected data demonstrates consistent agreement in the MCP joint flexion angle measurements between the two measurement methods. This consistency up until 10 kPa validates the precision of the experimental setup and suggests reliable system performance across different configurations, as illustrated in Fig. 15.

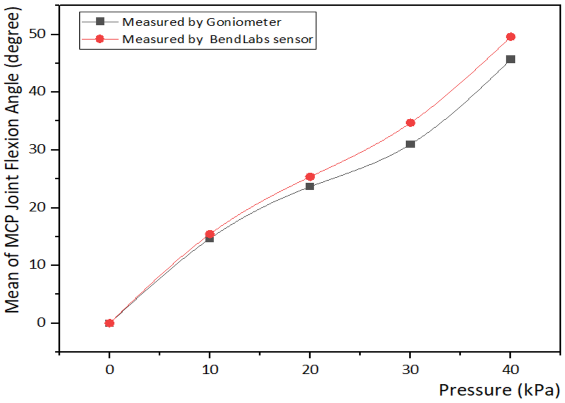


Fig 15. MCP joint flexion angle versus input pressure.

Table 2 and Table 3 display the flexion angle data obtained from measurements using a bend sensor and goniometer. The data presented in Table 3 reveal that the BendLabs sensor displayed inconsistent performance in terms of accuracy across the tested pressure ranges, with the most substantial deviations observed at 30 kPa (11.98 % error) and 40 kPa (8.62 % error) when benchmarked against the Goniometer reference measurements. This level of error surpassed the anticipated accuracy threshold of less than 5 % for the sensor.

Table 2. MCP joint flexion angle measured by goniometer.

Pressure (kPa)	MCP Joint Flexion Angle (degree) by Goniometer					
	1st trial	2nd trial	3rd trial	Mean	SD	CV
0	0.0	0.0	0.0	0.0	0.0	undefined
10	15.0	14.0	15.0	14.7	0.6	3.9
20	23.0	25.0	23.0	23.7	1.2	4.9
30	31.0	31.0	31.0	31.0	0.0	0.0
40	46.0	45.0	46.0	45.7	0.6	1.3

Table 3. MCP joint flexion angle measured by Bendlabs sensor.

Pressure (kPa)	MCP Joint Flexion Angle (degree) by BendLabs Sensor					
	1st trial	2nd trial	3rd trial	Mean	SD	CV
0	0.02	0.03	0.02	0.02	0.01	24.74
10	14.89	16.03	15.41	15.44	0.57	3.70
20	28.41	23.92	23.81	25.38	2.62	10.34
30	34.39	34.70	35.05	34.71	0.33	0.95
40	47.86	49.48	51.47	49.60	1.81	3.65

Furthermore, the data suggest that the BendLabs sensor exhibited high variability in its measurements at the initial 0 kPa pressure, as evidenced by a Coefficient of Variation (CV) of 24.7 %. The CV can be computed by dividing the mean by the Standard Deviation (SD) and multiplying the result by 100. This high level of relative variability raises potential concerns regarding the consistency and stability of the sensor's performance at the initial stage. In contrast, the Goniometer demonstrated superior repeatability, especially under higher pressure conditions. The data quality may have been compromised by improper installation of the bend sensor, particularly in the way it was attached to the glove.

4 Conclusion

This paper presents the design, fabrication, and evaluation of a segmented pneumatic soft actuator, which demonstrates its potential for effective hand rehabilitation. The actuator's ability to mimic natural finger movements, coupled with the precise sensor integration, highlights its promising capabilities for enhancing finger flexion in a rehabilitation glove. The segmented bending actuator developed for assisting finger flexion demonstrates success in its design and performance. The input pressure-elongation length and input pressure-MCP joint flexion angle relationships provides valuable insights into the actuator's flexibility under varying pressure conditions, offering significant potential in soft robotics applications. Future research should explore materials that balance flexibility and rigidity, enhancing the actuator’s ability to flex, extend, and transmit force, thereby improving its effectiveness in supporting finger rehabilitation exercises.

Conflict of Interest

The authors declare no conflict of interest.

Author Contributions

N. H. Rodzuan as the first author contributes in Research & Investigation, Analysis and Original Draft Preparation. I. N. A. M. Nordin as the second and corresponding author contributes in Idea & Conceptualization, Methodology, Funding Acquisition, Project Administration, Research & Investigation, Supervision and Revise & Editing. A. A. M. Faudzi as the third author contributes in Supervision, N. Zulkarnain as the fourth author contributes in Analysis, M. R. M. Razif as the fifth author contributes in Methodology, N. N. M. Hassan as the sixth author contributes in Revise & Editing and M. H. A. Hafidz as the seventh author contributes in Methodology.

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References

[1] N. R. Nik Nasihah, A. Asokan, D. Mayakrishnan, and H. Annamalai, "Exploring Stroke Rehabilitation in Malaysia: Are Robots Better than Humans for Stroke Recuperation?" Malaysian Journal of Medical Sciences, Vol. 28, No. 4, pp. 14–23, Aug. 2021. https://doi.org/10.21315/mjms2021.28.4.3

[2] F. Li, J. Chen, G. Ye, S. Dong, Z. Gao, and Y. Zhou, "Soft Robotic Glove with Sensing and Force Feedback for Rehabilitation in Virtual Reality," Biomimetics, Vol. 8 (1), No. 83, pp. 1-15, Feb. 2023. https://doi.org/10.3390/biomimetics8010083

[3] Y. Hao and Y. Visell, "Beyond Soft Hands: Efficient Grasping with Non-Anthropomorphic Soft Grippers," Frontiers in Robotics and AI, Vol. 8, No. 632006, pp. 1-8, Jul. 2021. https://doi.org/10.3389/frobt.2021.632006

[4] C. Y. Chu and R. M. Patterson, "Soft Robotic Devices for Hand Rehabilitation and Assistance: A Narrative Review," Journal of NeuroEngineering and Rehabilitation, Vol. 15, No. 9, pp. 1-14, Feb. 2018. https://doi.org/10.1186/s12984-018-0350-6

[5] D. H. Kim, Y. Lee, and H.-S. Park, "Bioinspired High-Degrees of Freedom Soft Robotic Glove for Restoring Versatile and Comfortable Manipulation," Soft Robotics, Vol. 9, No. 4, pp. 734-744, Aug. 2022. https://doi.org/10.1089/soro.2020.0167

[6] M. Li, T. Wang, Y. Zhuo, B. He, T. Tao, J. Xie, and G. Xu "A Soft Robotic Glove for Hand Rehabilitation Training Controlled by Movements of the Healthy Hand," in Proc. 17th Int. Conf. Ubiquitous Robots (UR), Jun Kyoto, Japan, 2020. https://doi.org/10.1109/ur49135.2020.9144753

[7] W. Thimabut, P. Terachinda, and W. Kitisomprayoonkul, "Effectiveness of a Soft Robotic Glove to Assist Hand Function in Stroke Patients: A Cross-Sectional Pilot Study," Rehabilitation Research and Practice, Vol. 2022, No. 738219, pp. 1-8, Apr. 2022. https://doi.org/10.1155/2022/3738219

[8] X. Chen, L. Gong, L. Wei, S. -C. Yeh, L. Da Xu, L. Zheng and Z. Zou, "A Wearable Hand Rehabilitation System with Soft Gloves," IEEE Transactions on Industrial Informatics, Vol. 17, No. 2, pp. 943–952, Feb. 2021. https://doi.org/10.1109/tii.2020.3010369

[9] K. Nuckols, W. Moyo, C. Hohimer, C. Glover, D. Wagner, A. Cloutier, D. Lin, and C. Walsh, "Proof of Concept of Soft Robotic Glove for Hand Rehabilitation in Stroke Survivors," Archives of Physical Medicine and Rehabilitation, Vol. 100, No. 12, pp. e195, Dec. 2019. https://doi.org/10.1016/j.apmr.2019.10.099

[10] P. Polygerinos, Z. Wang, K. C. Galloway, R. J. Wood, and C. J. Walsh, "Soft Robotic Glove for Combined Assistance and At-Home Rehabilitation," Robotics and Autonomous Systems, Vol. 73, No. November 2015, pp. 135–143, Nov. 2015. https://doi.org/10.1016/j.robot.2014.08.014

[11] N. Gao, P. Chen, and L. Liang, "BCI–VR-Based Hand Soft Rehabilitation System with Its Applications in Hand Rehabilitation after Stroke," Int. J. Precision Eng. Manuf., Vol. 24, No. 8, pp. 1403–1424, June 2023. https://doi.org/10.1007/s12541-023-00835-2

[12] S. N. S. Selamat, R. C. Me, H. A. Ainuddin, M. S. F. Salim, H. R. Ramli, and M. H. Romli, "The Application of Technological Intervention for Stroke Rehabilitation in Southeast Asia: A Scoping Review with Stakeholders' Consultation," Frontiers in Public Health, Vol. 9, No. 783565, pp. 1-12, Feb. 2022. https://doi.org/10.3389/fpubh.2021.783565

[13] I. N. A. M. Nordin, M. R. M. Razif, A. A. M. Faudzi, E. Natarajan, K. Iwata, and K. Suzumori, "3-D Finite-Element Analysis of Fiber-Reinforced Soft Bending Actuator for Finger Flexion," in Proc.

IEEE/ASME Int. Conf. Adv. Intell. Mechatronics (AIM), Wollongong, NSW, Australia, 2013. https://doi.org/10.1109/aim.2013.6584080

[14] I. N. A. M. Nordin, A. A. M. Faudzi, M. Z. Kamarudin, D. E. O. Dewi, T. Rehman, and M. R. M. Razif, "Grip Force Measurement of Soft-Actuated Finger Exoskeleton," Jurnal Teknologi, Vol. 78, No. 6–13, pp. 25-30, June 2016. https://doi.org/10.11113/jt.v78.9268

[15] F. Yang, Q. Ruan, Y. Man, Z. Xie, H. Yue, B. Li and R. Liu "Design and Optimize of a Novel Segmented Soft Pneumatic Actuator," IEEE Access, Vol. 8, pp. 122304–122313, July 2020. https://doi.org/10.1109/ACCESS.2020.3006865

[16] G. Belforte, G. Eula, A. Ivanov, and S. Sirolli, "Soft Pneumatic Actuators for Rehabilitation," Actuators, Vol. 3, No. 2, pp. 84–106, May 2014. https://doi.org/10.3390/act3020084

[17] B. Wang, A. McDaid, M. Biglari-Abhari, and K. C. Aw, "Design and Development of a Glove for Post-Stroke Hand Rehabilitation," in Proc. IEEE Int. Conf. Adv. Intell. Mechatronics (AIM), Munich, Germany, 2017. https://doi.org/10.1109/aim.2017.8014157

[18] K. Nuckols, C. J. Hohimer, C. Glover, D. S. de Lucena, W. Moyo, D. Wagner, A. Cloutier, D. J. Lin, and C. J. Walsh, "Effects of a Soft Robotic Glove Using a High Repetition Protocol in Chronic Stroke: A Pilot Study," in Proc. 8th IEEE RAS/EMBS Int. Conf. Biomed. Robot. Biomechatronics (BioRob), New York, USA 2020. https://doi.org/10.1109/biorob49111.2020.9224291

[19] J. Wang, Y. Fei, and W. Pang, "Design, Modeling, and Testing of a Soft Pneumatic Glove with Segmented PneuNets Bending Actuators," IEEE/ASME Transactions on Mechatronics,Vol. 24, No. 3, pp. 990-1001, June 2019. https://doi.org/10.1109/TMECH.2019.2911992

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