Journal of Engineering Science and Technology
Vol. 17, No. 2 (2022) 0985 - 0996

COMPUTATIONAL ANALYSIS OF ANKLE-FOOT ORTHOSIS FOR FOOT DROP CASE DURING STANCE PHASE IN GAIT CYCLE

ALFIAN PRAMUDITA PUTRA[1,2,*], AKIF RAHMATILLAH[1,2], NUR KHAFIDOTUR RODHIYAH[1], PUJIYANTO[3], I PUTU ALIT PAWANA[4]

[1]Biomedical Engineering Study Program, Department of Physics, Faculty of Science and Technology, Universitas Airlangga, 60115, Surabaya, Indonesia
[2]Biomedical Signals and Systems Research Group, Faculty of Science and Technology, Universitas Airlangga, 60115, Surabaya, Indonesia
[3]Department of Physics, Faculty of Science and Technology, Universitas Airlangga, 60115 Surabaya, Indonesia
[4]Department of Physical Medicine and Rehabilitation, Dr. Soetomo General Academic Hospital, 60248, Surabaya, Indonesia
*Corresponding Author: alfian.pramudita@fst.unair.ac.id

Abstract

Foot drop is a neuromuscular disorder characterised by steppage in the gait cycle that hinders a patient from performing dorsiflexion or lifting the forefoot. This condition is commonly found in patients with stroke or cerebral palsy. A device treats foot drop conditions for rehabilitation, such as the use of Ankle-Foot Orthosis. The fabrication process of Ankle-Foot Orthosis is usually performed for a specific case and customised for a single person. Trial and error in the fabrication process are commonly chosen to obtain the correct design. Thus, a computational study is needed to provide less time and cost in designing the Ankle-Foot Orthosis. This study aims to observe the Ankle-Foot Orthosis model simulation for foot drop cases in the stance phase. The model was developed and analysed by using Solidworks. The result showed that the highest stress was concentrated on the lateral ankle curvature or ankle trimline of the Ankle-Foot Orthosis in the initial contact subphase. The stress was still below the elastic modulus of polypropylene which was the material used in the simulation. Using this Ankle-Foot Orthosis model, the patient with foot drop would provide artificial dorsiflexion and improve the gait cycle to prevent stumbling.

Keywords: Ankle foot orthosis, Computational analysis, Foot drop, Health care, Rehabilitation, Stance phase.

1. Introduction

Some people suffer from abnormalities in how they walk due to a disease, accident, or other reasons. Several treatments are introduced to overcome that problem, such as using an orthosis, stimulation using an electrical stimulator, or physical rehabilitation. Eight hundred sixty-six million people in the USA needed lower limb orthoses to assist them daily [1]. In Indonesia, 12 out of 100 people had difficulty walking long, combined with difficulty standing for 30 minutes [2]. One of the issues related to this was foot drop. It is a neuromuscular disorder characterised by steppage in the gait cycle that gives the patient trouble in dorsiflexion or lifting the forefoot. This condition is characterised by excess plantarflexion and the inability to perform the dorsiflexion or move the toe upward [3]. The main factor that causes foot drop includes muscle dysfunction, peroneal nerve disorder, sciatic nerve disorder, and lumbosacral plexus damage [4].

A patient with foot drop has a problem with active dorsiflexion. Muscle innervation can be disturbed so that the muscle's necessary contraction capacity is diminished or completely gone. In this case, the patient can still walk on tiptoes because the patient's active plantarflexion (gastrocnemius/soleus muscles) is still active. However, during the swing phase, the foot is in a plantarflexion position. Therefore, there is no foot clearance, resulting in stumbling or falling [5, 6]. A patient with foot drop tends to be in the initial contact subphase with the floor for a more extended period. The Ground Reaction Force (GRF) at initial contact is at the heel and moves forward by the unaffected plantar flexors' contraction. Artificial dorsiflexion during the swing phase is needed to prevent passive plantar flexion. This case can be organised by an orthotic device, such as an Ankle-Foot Orthosis (AFO) [7, 8].

Foot drop is treated by rehabilitation to give restorative treatment in maximising the healing process. The development of rehabilitation devices has become prominent due to its high demand. A device used in rehabilitation for foot drop cases is Ankle Foot Orthosis (AFO), which supports the lower limb, especially the ankle [9]. It is a medical device that can correct disorders of the foot. The AFO covers the foot and calf of the leg to fixate the ankle and support the leg position so that the user can walk normally. AFO assists the users by fixing the ankle to stay in its position and avoiding extra plantarflexion in foot drop conditions [10].

Ankle-Foot Orthoses (AFO) have been widely and commonly used for rehabilitation purposes, especially in a drop foot case due to stroke or cerebral palsy [11-13]. Polymer-based AFO becomes preferred by orthotists because it is easily shaped and thermoplastic. However, it also gives some critical points in the design when there is a stress concentration during the users' gait cycle. Those points would trigger cracks or fractures in a particular section of the AFO [14, 15]. Besides that, the cracking progression would limit the durability of AFO while it is expected to be used for the long term in daily living. Because of that, the orthotists must prescribe the new AFO, which is ineffective. This device's durability and effectiveness should be maintained to decrease the cost and healing time for the patients.

AFO would give better stability at the stance and improve the patient's walking speed and cadence [16, 17]. The rigid non-articulated AFO is preferable for the drop foot case with stability problems due to its high stiffness level and the stress distribution on a broader area. By changing the trim lines and the material, the stiffness of the AFO could be altered to achieve the desired properties.

The fabrication of AFO nowadays still uses a trial-error concept, resulting in an inefficient fabrication process [18, 19]. The physician measured the patient's foot's dimension and designed a suitable AFO for that particular patient. The patient was asked to wear the AFO and analysed in the motion lab. If the patient did not feel comfortable or the gait is not correct, then the physician would give another design to try. This process is ineffective and inefficient in terms of time and cost. The failure of AFO was reported in several studies related to the stress distribution on the AFO design [14, 15]. This condition also occurred in the department of physical medicine and rehabilitation of Dr. Soetomo General and Academic Hospital, Surabaya, Indonesia. The prescribed AFO was cracked after being used several days by the patient. The cracking site happened in the curvature around the ankle. The maximum stress in this particular section might be beyond the yield strength of the material. A simulation could be performed to analyse the failure condition of AFO to mitigate this condition, especially in fracture conditions during the gait cycle [20, 21].

Previously conducted studies used the Finite Element Method (FEM) to simulate and evaluate the AFO model [15, 22]. The FEM gives information on mechanical behaviour and the location of stress concentrations. Knowing this information before manufacturing the device would give more benefit in terms of time and waste production [18]. To the best of our knowledge, there is no study about the evaluation of AFO for the foot drop case in the three subphases of the stance phase in the gait cycle computationally. This study could help the medical practitioners prescribe an AFO to the patients in giving the best design without undergoing the trial-error approach which could crack if a high load is applied to that particular location. Besides that, this study could give insight to the orthotist about the optimal design used for a dorsal AFO. In this study, we aimed to evaluate the design of AFO on foot drop cases using finite element analysis and its prediction in fracture condition during the gait cycle, especially stance phase, which consists of three subphases; initial contact, midstance, and terminal stance. Evaluating the correct AFO will help the fabrication process of AFO without failure due to the cracking. The result of this study can also be used as an input for 3D printed AFO.

2. Materials and Methods

The design process was performed based on a specific condition of the foot drop case. This condition requires an AFO with full support called Posterior Leaf Spring AFO, a type of AFO for patients who need dorsiflexion assistance [23]. The type of AFO designed was a dorsal AFO because it supports the foot's rear and gives artificial dorsiflexion. The geometry was developed based on the average dimension of feet in Indonesia, such as the foot length, foot width, and calf height.

The geometrical dimension of the design was simplified into a design with several parameters that could be adjusted. These parameters were foot support, foot width, calf height, calf curvature, lateral ankle curvature, medial ankle curvature, and medial plantar arch. The parameters and dimensions of the design are shown in Fig. 1 [24].

After the design was modelled in Solidworks 2019, the design was inserted into the finite element simulation process in Solidworks SimulationXpress. The simulation started by applying several forces indicating the condition of foot drop in the gait cycle. This information was based on the Ground Reaction Force (GRF) of a patient with foot drop in Dr. Soetomo General Hospital quantified by a force plate (Advanced Mechanical Technology, Inc., US) and cameras (Basler, Germany) and processed by a Clinical Motion Analysis Xystem (CMAX) software. The focus in this study is the GRF on initial contact, mid-stance, and terminal stance. The GRF in this study was focused on the initial contact, mid-stance, and terminal stance in the stance phase.

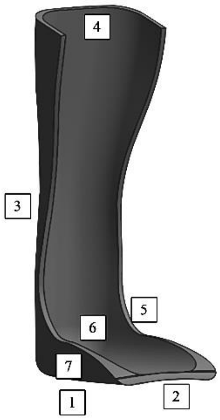


Fig. 1. Geometry Parameters in the Simplified Design (Note: (1) foot support (length: 18.4 cm), (2) foot width (width: 10.64 cm), (3) calf height (height: 28.6 cm), (4) calf curvature (radius: 1.5, angle: 90°), (5) lateral ankle curvature (radius: 2 cm; curvature: 3.2 cm), (6) medial ankle curvature (radius: 1.5 cm, curvature: 2.35 cm), and (7) medial plantar arch (no arch)).

The finite element simulation was performed on the model regarding three subphases in the stance phase: initial contact, midstance, and terminal stance. The boundary condition used was a fixed constraint at the upper part of the AFO since this part is supposed to be fixed and immovable. The external force was applied at the bottom of the foot representing the Ground Reaction Force (GRF) when the patient walks. The external force was a vertical load of 500 N to indicate the patient's weight (50 kg). The external force position was based on the foot's contact position with the gait cycle floor. The mesh of the model was generated with 269584 nodes and 171575 elements of tetrahedral shape.

The AFO design was proposed for the simulation. Polypropylene copolymer was used for the simulation with properties: tensile strength of 27.7 MPa, the elastic modulus of 896 MPa, the density of 890 kg/m^3, and Poisson's ratio of 0.413. This material is commonly used in AFO. The simulation results give information about the von Misses stresses, deformation, and strain of the model in each step of the stance phase. The distribution of these parameters was analysed to avoid cracking due to surpassing the Ultimate Tensile Strength.

3. Results and Discussion

The AFO was successfully designed with specific dimensions. The model's simulation was performed, and the result of von Mises stress, deformation, and the strain of the model with three subphases in the stance phase, which were initial contact, mid stance, and terminal stance, were analysed. The force applied in these three conditions was a maximum of 500 N vertically based on data of a patient with foot drop. The vertical GRF was chosen because it has the highest component. The anteroposterior and mediolateral forces of GRF are negligible if they are compared to the vertical GRF [25].

Figures 2, 3, and 4 show the simulation's result in von Mises stress, strain, and deformation for three subphases in the gait cycle's stance phase. The maximum values of von Mises stress, deformation, and strain from three different subphases in the stance phase are shown in Table 1. The maximum stress location in all simulations was on the ankle trimline or position no. 5, shown in Figure 1. The maximum strain for all the simulations was also on the exact location as the maximum stress. The maximum deformation was located on the tip of the footplate.

On the other hand, the minimum stress was located on the footplate's tip or the superior-inferior top part of the AFO. Minimum deformation was also found at the superior-inferior of the AFO since it is the fixed support location that did not move. Minimum strain could be found at the tip of the footplate.

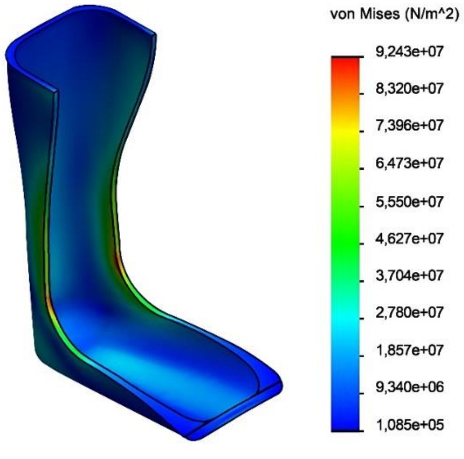
The highest von Mises stress was found in the AFO simulation during initial contact. This subphase is the first part of AFO, which had contact with the floor during the gait cycle. During initial contact, the centre of rotation is the ankle, which was expected to be rigid to give the user more stability. The highest stress located in the ankle trimline needs to be thicker to withstand the material's cracking. On the other hand, the highest strain was also found in the exact location as the highest von Mises stress, indicating that this part should have thicker material.

Table 1. The Finite Element Analysis of dorsal AFO for drop foot case in stance phase regarding three parameters (a) von Mises stress, (b) Deformation, and (c) Strain.

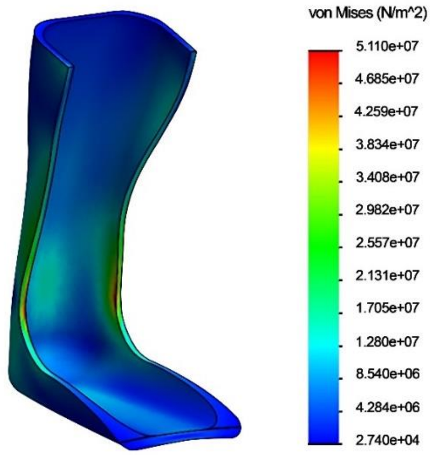
Parameter	Subphase in Gait Cycle		
	Initial Contact	Midstance	Terminal Stance
Maximum Von Mises Stress (MPa)	92.43	51.1	44.93
Maximum Deformation (mm)	58.37	25.3	25.3
Maximum Strain	0.00402	0.00385	0.00472

The loads applied in the footplate led to stress concentration in the ankle trimline because the centre of rotation is around the ankle (aligned with the fixed constraint). During the initial contact, the contact area is the smallest among the other subphases. Thus, the von Mises stress during initial contact was the highest. The role of material type is also significant in this simulation. Polypropylene is the standard material used for AFO due to its thermoplastic properties.

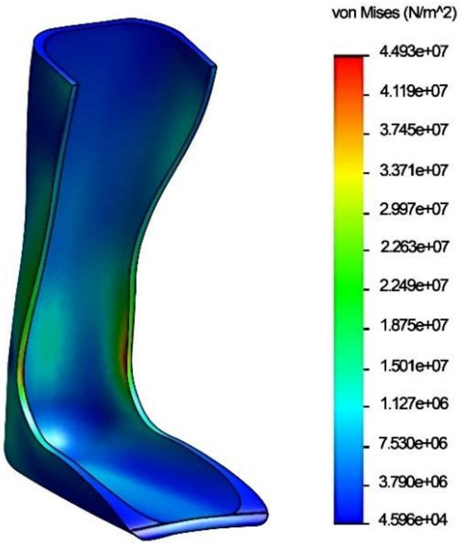
The result in Table 1 showed that the stress was concentrated in the lateral ankle curvature or ankle trimline, which reached the highest value in the initial contact at 92.43 MPa. It decreased in the midstance and terminal stance, as shown in Table 1. The area of concentrated stress was similar to the crack's location in the case of AFO commonly used by the patient [1, 26]. The design of dorsal AFO indicated that most of the stress from the foot assembles in the lateral and medial part of the ankle curvature. The force applied to the AFO originated from the Ground Reaction Force (GRF) due to the gait cycle of the AFO user or the force applied to the AFO by the user's foot. When the user decelerated in the initial contact, the GRF was concentrated in the foot's heel. In the foot drop case, the presence of AFO prevents the foot from falling to the ground in the initial contact. Besides that, in the terminal stance, the users of AFO tend to lift their foot instead of undergoing the terminal stance since the AFO prevents the plantarflexion of the foot [27].



(a) Initial Contact.

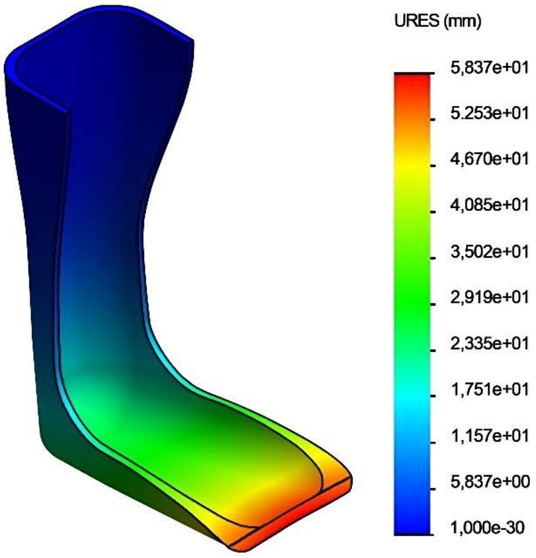


(b) Mid Stance.

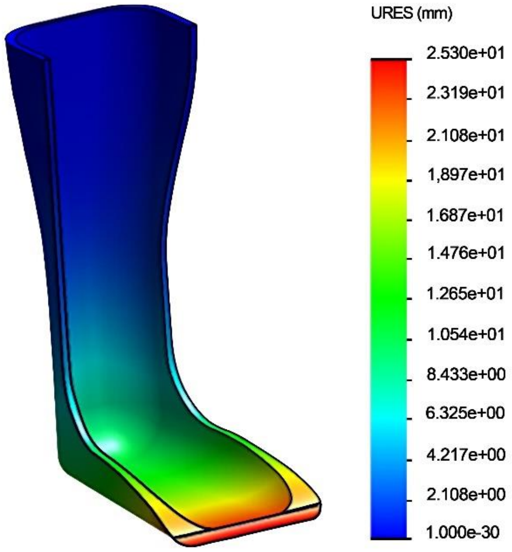


(c) Terminal stance.

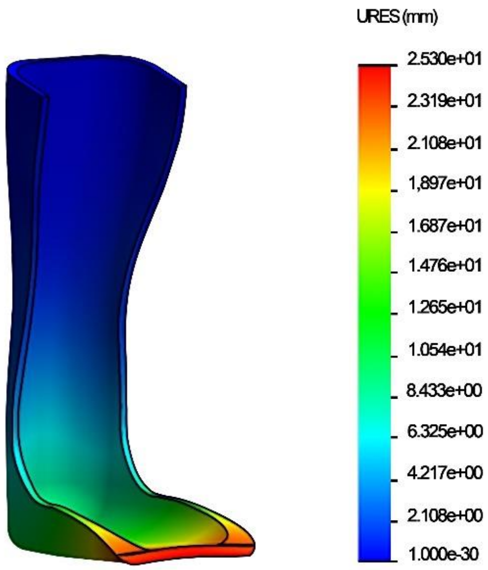
Fig. 2. The von Mises stress of dorsal ankle-foot orthosis in three different subphases of stance phase in gait cycle.



(a) Initial Contact.

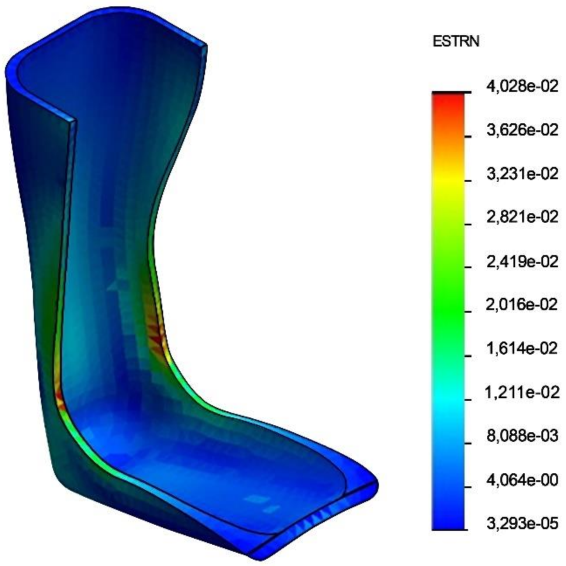


(b) Mid Stance.

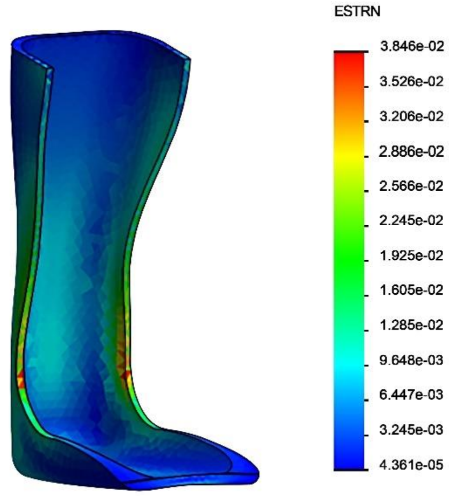


(c) Terminal stance.

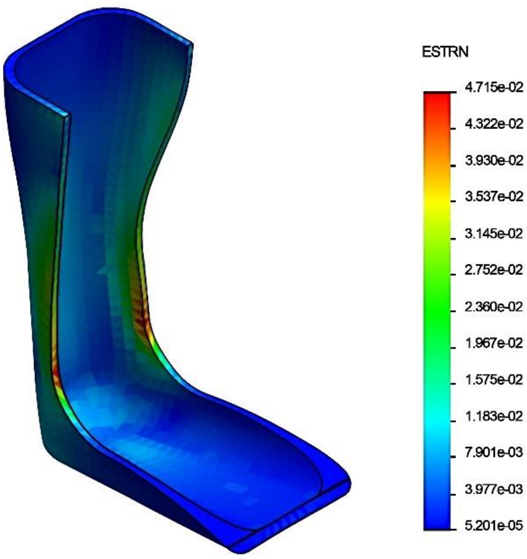
Fig. 3. The deformation of dorsal ankle-foot orthosis in three different subphases of stance phase in gait cycle.



(a) Initial Contact.



(b) Mid Stance.



(c) Terminal stance.

Fig. 4. The strain of dorsal ankle-foot orthosis in three different subphases of stance phase in gait cycle.

Foot drop is a consequence of a disease, trauma, or accident. When the anterior tibial muscle is affected, the foot drop can be easily compensated by a simple dorsal AFO. The material stiffness is sufficient for keeping the foot in a fixed position of

90° during the swing phase. The shape is flexible and stiff, enabling dorsal flexion during the stance phase and plantar flexion during push-off. Another advantage for the patient is the light-weighted material [13, 28].

Based on the simulation result, the proposed model of AFO showed the highest stress in the AFO when it was in the initial contact subphase. That was the first contact between the foot and the floor covered by the heel's small area. This value was still lower than the model's material's elastic modulus, which indicated that that result was safe. However, the presence of the concentrated stress would likely be the location of the crack after the AFO is used in an extended amount of time. The AFO was quite stiff because of this material, and this property was beneficial since the AFO keeps the foot in a dorsiflexion position and prevent plantarflexion. This benefit was also mentioned by the previous studies conducted by Ielapi et al. [27] and Banga et al. [29]. This condition also initiated the beginning of the gait cycle, which is the heel's initial contact instead of the forefoot. The most considerable deformation also happened in the initial contact phase. The AFO deformed mainly in the initial contact position since the most significant stress was concentrated in this step. The tip of the AFO deforms from its initial position when force is applied. This deformation was still normal since this condition only stays for 10% of the stance phase.

In the foot drop case, the use of AFO aimed to have more foot clearance, especially in the terminal stance, since the patient could do the foot's dorsiflexion. The maximum stress found in the AFO during terminal stance indicated that the AFO could withstand the GRF from the user and give foot clearance right after the terminal stance. The deformation and strain of AFO during the terminal phase were also the lowest among the other two subphases in the stance phase. This AFO design could be used in the foot drop case with the same type of material as the simulation. This study's future challenge is to perform the experimental setup to test the design with the user's proposed material, and his gait will be analysed.

This study focuses only on one loading for one patient-specific AFO. The model only showed the mechanical behaviour during static analysis, but the devices' response during fatigue is not modelled. The straps used to fix the patient leg on the AFO could have been modelled for future study. The presence of straps could increase the model's complexity since there is contact between the strap and the AFO [27]. For further study, the boundary condition should be set similar to the loading during gait. The interaction between the AFO, foot and insole also could be modelled.

4. Conclusions

A dorsal ankle-foot orthosis was explicitly designed for foot drop cases. The simulation of this design in the stance phase showed that the model could withstand the force representing the user's ground reaction force with a bodyweight of 50 kg. The model's stress was concentrated in the lateral ankle curvature with a value below its modulus elasticity, indicating that it is safe to use. This study's future possibility is implementing this model through additive manufacturing or 3D printing technology to evaluate its properties, especially during the gait cycle. The fatigue analysis should be performed in the simulation to observe the durability of this AFO design.

Abbreviations	
AFO	Ankle Foot Orthosis
GRF	Ground Reaction Force

References

1. Zou, D.; He, T.; Dailey, M.; Smith, K.E.;, Silva, M.J.; Sinacore, D.R.; Mueller, M.J.; and Hastings, M.K. (2014). Experimental and computational analysis of composite ankle-foot orthosis. *Journal of Rehabilitation Research and Development*, 51(10), 1525-1536.
2. Kemenkes. (2013). Riset Kesehatan Dasar (Jakarta).
3. Hassan, F.; Murtaza, Q.; and Bhardwaj, S. (2017). Manufacture, design and structural analysis of a custom ankle foot orthoses on foot drop patients using 3D scanning. *International Journal of Scientific and Engineering Research*, 8(7), 201-203.
4. Jamshidi, N.; Rostami, M.; Najarian, S.; Menhaj, M.B.; Saadatnia, M.; and Firooz, S. (2009). Modelling of human walking to optimise the function of ankle-foot orthosis in Guillan-Barré patients with drop foot. *Singapore Medical Journal*, 50(4), 412-417.
5. Carolus, A.E.; Becker, M.; Cuny, J.; Smektala, R.; Schmieder, K.; and Brenke, C. (2019). The interdisciplinary management of foot drop. *Deutsches Arzteblatt International*, 116(20), 347-354.
6. Kluding, P.M.; Dunning, K.; Dell, M.W.O.; Wu, S.S.; Ginosian, J.; Feld, J.; and Mcbride, K. (2013). Foot drop stimulation versus ankle foot orthoses after stroke: 30-week outcomes. *Stroke*, 44(6), 1660-1669.
7. Hamedi, M.; Salimi, P.; Aliabadi, A.; and Vismeh, M. (2015). Toward intelligent ankle foot orthosis for foot- drop: A review of technologies and possibilities. 2015 2*nd International Conference on Biomedical Engineering* (*ICoBE*), Penang, Malaysia, 1-6.
8. Stevens, F.; Weerkamp, N.J.; and Cals, J.W.L. (2015). Foot drop. *BMJ Learning*, 350:h1736.
9. Garcia, E.; Sanz-Merodio, D.; Cestari, M.; Perez, M.; and Sancho, J. (2016). An active knee orthosis for the physical therapy of neurological disorders *Robot* 2015*: Second Iberian Robotics Conference ed* (Cham: Springer International Publishing), 327-337.
10. Alam, M.; Choudhury, I.A.; and Mamat, A. Bin. (2014). Mechanism and design analysis of articulated ankle foot orthoses for drop-foot. *The Scientific World Journal*, Volume 2014, Article ID 867869.
11. Bleyenheuft, C.; Deltombe, T.; and Detrembleur, C. (2013). Influence of ankle-foot orthoses on kinematic segmental covariation among stroke patients. *Annals of Physical and Rehabilitation Medicine*, 56(1), 3-13.
12. Dogan, A.; Mengulluoglu, M.; and Ozgirgin, N. (2011). Evaluation of the effect of ankle-foot orthosis use on balance and mobility in hemiparetic stroke patients. *Disability and Rehabilitation*, 33(15-16), 1433-1439.
13. Kim, J.; Hwang, S.; Sohn, R.; Lee, Y.; and Kim, Y. (2011). Development of an active ankle foot orthosis to prevent foot drop and toe drag in hemiplegic

patients : A preliminary study. *Applied Bionics and Biomechanics*, 8, Article ID 530375, 377-384.

14. Gomes, G.; Lourenço, I.; Oliveira, J.; Gomes, M.; Vale, A.; Freire, L.; Quental, P.; Policarpo, H.; and Matos, J. (2017). Structural reinforcements on AFO's: A study using Computer-Aided Design and finite element method. *IEEE* 5*th Portuguese Meeting on Bioengineering* (*ENBENG*), 1-4.
15. Volpini, M.; Alves, D.; Horta, A.; Borges, M.; and Reis, P. (2018). Orthosis and finite elements : A study for development of new designs through additive manufacturing. *International Journal of Biomedical and Biological Engineering*, 12(6), 262-266.
16. Chen, C.-C.; Hong, W.-H.; Wang, C.-M.; Chen, C.-K.; Wu, K.P.-H.; Kang, C.-F.; and Tang, S.F. (2010). Kinematic features of rear-foot motion using anterior and posterior ankle-foot orthoses in stroke patients. *Archive of Physical Medicine and Rehabilitation*, 91(12), 1862-1868.
17. Hung, J-W.; Chen, P-C.; Yu, M-Y.; and Hsieh, Y-W. (2011). Long-term effect of an anterior ankle-foot orthosis on functional walking ability of chronic stroke patients. *American Journal of Physical Medicine and Rehabilitation*, 90(1), 8-16.
18. Ielapi. A.; Lammens, N.; Paepegem, W. Van.; Forward, M.; Deckers, P.; Vermandel, M.; and Beule, M. De. (2019). A validated computational framework to evaluate the stiffness of 3D printed ankle foot orthoses. *Computer Methods in Biomechanics and Biomedical Engineering*, 22(8), 880-887.
19. Cha, Y.H.; Lee, K.H.; Ryu, H.J. Joo, I.W.; Seo, A.; Kim, D.; and Kim, S.J. (2017). Ankle-foot orthosis made by 3d printing technique and automated design software. *Applied Bionics and Biomechanics*, Volume 2017, Article ID 9610468.
20. Rahimi-Gorji, M.; Basak, S.; Debbaut, C.; Descamps, B.; Pullens, P.; Segers, P.; Sourbron, S.; and Ceelen, W. (2019). Validation of a computational fluid dynamics model of drug delivery and intertitial fluid pressure in ovarian cancer xenograft. *SB*3*C*2019-*Summer Biomechanics*, *Bioengineering and Biotransport Conference* (Seven Springs, Pennsylvania, US)
21. Rahimi-Gorji, M.; Van de Sande, L.; Debbaut, C.; Segers, P.; Willaert, W.; and Ceelen, W. (2019). Computational fluid dynamics model of pressurized intraperitoneal aerosol chemotherapy : gravity matters! *SB*3*C*2019-*Summer Biomechanics*, *Bioengineering and Biotransport Conference* (Seven Springs, Pennsylvania, US).
22. Putra, A.P.; Rahmatillah, A.; Pujiyanto; Ain, K.; Rodiyah, N.K.; Pawana, I.P.A.; Syahananta, L.H.D.; Dwiatma, M.R.; and Hidayat, A.S. (2021). Computational study of ventral ankle-foot orthoses during stance phase for post-surgery spinal tuberculosis rehabilitation. *Proceedings of the* 1*st International Conference on Electronics*, *Biomedical Engineering*, *and Health Informatics*, *Lecture Notes in Electrical Engineering*, 746, 447-55.
23. Kerr, E.; Moyes, K.; Arnold, G.; and Drew, T. (2011). Permanent deformation of posterior leaf-spring ankle-foot orthoses: A comparison of different materials. *Journal of Prosthetics and Orthotics*, 23(3), 144-148.
24. Faustini, M.C.; Neptune, R.; Crawford, R.H.; and Stanhope, S.J. (2008). Manufacture of passive dynamic ankle - foot orthoses using selective laser sintering. *IEEE Transaction on Bio-Medical Engineering*, 55(2), 784-790 .

25. Bas, K.W.B.S.; Sjouke, Z.; Wiebren, Z.; and Ida, B. (2012). Comparison of vertical ground reaction forces during overground and treadmill running. A validation study. *BMC Musculoskeletal Disorders*, 13(1), 235.
26. Marques, M.A.; Mendes, E.; Ramos, N.V.; Pinto, V.C.; and Vaz, M.A. (2010) Finite element analysis of ankle foot orthosis to predict fracture conditions during gait Finite-element analysis of ankle-foot orthosis to predict fracture conditions during gait. 1*st ICH Gaia-Porto*, Portugal.
27. Ielapi, A.; Forward, M.; and De Beule, M. (2019). Computational and experimental evaluation of the mechanical properties of ankle foot orthoses: A literature review. *Prosthetics and Orthotics International*, 43(3), 339-348.
28. Uning, R.; Abu Osman, N.A.; and Rahim, R.B.A. (2008). 3D finite element analysis of ankle-foot orthosis on patients with unilateral foot drop : A preliminary study. 4*th Kuala Lumpur International Conference on Biomedical Engineering*, 21, 366-369.
29. Banga, H.K.; Kalra, P.; and Dhole, S. (2017). To study the effect of ankle foot orthosis during walking of foot drop patients. *International Journal of Engineering TEchnology Science and Research*, 4(1), 175-182.