SIMULATION OF THE ANKLE FOOT ORTHOSES WITH PREVENTION DESIGN FOR PRONATION AND SUPINATION

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Dedicated, in thankful appreciation for support and encouragement to my beloved wife Nur Izmira binti Mohamad Radzi, my parent,, families and friends.

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ABSTRACT

Ankle rehabilitation has always been a gap for rehabilitation sciences. This is due to the lack of medical instrumentation and research that covers injuries especially on the supination and pronation effects. Here an extension method for ankle-foot orthoses with preventive design for pronation and supination with ankle dorsiflexion and plantar flexion will be utilized. For the dorsiflexion and plantar flexion mechanism, the proposed system will use the momentum based forward movement with braking system. While for extension design for pronation and supination will be based on hybrid passive and active actuator approach. The extension approach is capable of providing pronation and supination positioning support mechanism. In order to establish the concrete relationship of ankle's moment a simulation was performed accordingly. This research proved a contemporary methodology of ankle-foot orthoses. It does have significance for ankle rehabilitation sciences.

ABSTRAK

Latihan pemulihan buku lali sentiasa menjadi jurang untuk sains pemulihan. Ini adalah kerana kekurangan peralatan perubatan dan penyelidikan yang merangkumi kecederaan terutama kesan sampingan *supination* dan *pronation*. Di sini satu kaedah lanjutan untuk orthosis buku lali kaki dengan reka bentuk pencegahan bagi *pronation* dan *supination* dengan *dorsiflextion* dan *plantarflextion* akan digunakan. Bagi *dorsiflextor* dan *plantarflextor*, sistem mekanisme akan menggunakan momentum pergerakan dengan sistem brek. Manakala bagi reka bentuk lanjutan untuk *pronation* dan *supination* akan lebih kepada pendekatan penggerak campuran diantara pasif dan aktif. Pendekatan penambah lanjutan mampu menyediakan sokongan kepada kedudukan mekanisme *pronation* dan *supination*. Usaha untuk membina hubungan yang kukuh antara masa pergelangan kaki, simulasi telah dilakukan dengan sewajarnya.. Kajian ini menyediakan satu kaedah baru untuk reka bentuk orthosis buku lali dan mampu menyelesaikan masalah yang besar untuk pemulihan buku lali semasa kecederaan.

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LIST OF ABBREVIATIONS

AFO	-	Ankle foot Orthoses
AAFO	-	Active Ankle foot Orthoses
ARM	-	Advanced RISC Machines
CAN	-	Controller Area Network
DOF	-	Degree of freedom
D/P	-	Dorsiflextor or Plantarflextor
EMG	-	Electromyography
GC	-	Gait Cycle
HC	-	Heel contact
IC	-	Initial Contact
GRFC	-	Ground Response Plantar Calcaneus
GRFF	-	Ground Response Parallel Forefoot
PID	-	Proportional Derivative Integral
P-AFO	-	Pneumatic Ankle Foot Orthoses
S/P	-	Supination or Pronation
STJN	-	Neutral position subtalar joint
STJP	-	Pronated position subtalar joint
STJS	-	Supinated position subtalar joint
TO	-	Toe Off

LIST OF SYMBOLS

θ	-	Angular kinetic motion of ankle Cosine
γ	-	Angular kinetic motion of ankle Sine

CHAPTER 1

INTRODUCTION

1.1 Introduction

Ankle Foot Orthoses (AFO) is a device to eliminate the impact of impairment to the lower limb neuromuscular motor system that affects gait. Current technologies of AFO mostly focus on actuators and can be combination of passive and active devices with control and modulated damping system. These systems are heavily being used towards creating an optimal, useful and practical orthoses. The idea is to make an orthosis that is capable of producing enough torque and power to move forward with enough propulsive force. However, to achieve the ideal orthosis requires a demanding design requirement, such as light weight, compact, high efficiency and low noise. Pronation and supination support is a critical issue towards ankle orthoses improvement. A device that always monitors and maintains the ankle, by aligning the tendons, stabilizing the joint and preventing feet from flattening and also uniformly distributes your weight. This can be archieved by fusing the biomechanics into a more ameliorate extension design and emphasizing onto shock- absorption with stabilization of the heel.

1.2 Problem Statement

The demands of designing wearable medical and human assist devices are pushing the limit of miniaturization. Most of the AFOs are bulky and stationary. Miniaturization could solve the issues on stationary system and change the perception of the AFO as an inconvenient system. AFOs are used to improve the impact to the lower limb neuromuscular motor system that affects pathological gait. Due to injuries on the lower limb system, the effect eventually creates abnormalities for gait movement. The AFO eliminates these abnormalities of pathological gait by creating a system that solves dorsiflexion and plantar flexion movement with pronation and supination positioning support system.

Also most AFOs focus on planar and dorsiflexion movement but neglects the critical issues on the impact of pronation and supination. Current design mostly focuses on the planar and dorsiflexion movement, as from pathological gait perspective it contributs most of the person's movability. Unfortunately that is referring to normal walking system. During injuries or recovery, the requirement for assisting device that is capable of executing the reaction of the user without user involving with the movement is much needed. Untethered system that is capable to perform planar and dorsiflexion movement with pronation and supination positioning support system will be critical towards the ankle rehabilitation.

1.3 Objectives

The first objective is to design and simulate the kinematic ankle movement using MATLAB and find the best optimization for the mechanical design. The expected result from the mathematical modeling of the system is a dynamic analysis which can provide data on ankle displacement versus gait cycle , moment (Nm) versus ankle angle , Force (F) of toe versus gait cycle and stability of the system.

The second objective is to design an embedded control system that will encounter the supination and pronation. The expected result on this is the time(s) vs Angle (degree) relationship and the stability of the controller.

The third objective is the integration between the mechanical system and embedded system. The expected result is the time response of displacement, kinematic analysis based upon motion and the stability of whole system.

1.4 Contribution

The contribution of this work is a novelty on actuator, controller and structure implementation. The actuator novelty is the use of active braking with dual acting passive springs to support pronation and supination motion. The controller is designed using a Propotional-Intergration-Derivative (PID) controller. The structure is developed using 3D printed parts for modularity, which are interchangeable and are easier to maintain.

1.5 Thesis Organization

This study consists of five chapters. Chapter two provides a comprehensive literature review on methods from past research works on pronation and supination support mechanism. Finally, based on the literature review the problems are identified.

Chapter three proposes the methodology. In this chapter, the methods and the fundamental approach on understanding pronation and supination is given. The methods consist of the study of muscles and joints that have a direct impact when the pronation and supination happens. Study on the kinematics of the ankle and will be used to design the actual hardware to support ankle pronation and supination.

In chapter four the results of the preventive design of pronation and supination will be provided. Discussions on the result of the project are also included in this chapter. Last but not least, chapter five concludes this work. Some comments and suggestions for future improvements are provided.

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