INVESTIGATION ON THE EFFECTS OF HUMAN WEIGHT ON INTERVERTEBRAL DISC AT HUMAN LUMBAR SPINE USING FINITE ELEMENT ANALYSIS

TAN KAH YIN

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SUPERVISOR'S DECLARATION

I have checked this report and the report can now be submitted to JK-PSM to be delivered back to supervisor and to the second examiner.

Signature : ....

Name of Supervisor: ....

Date : ....

DECLARATION

I declare that this project report entitled “Investigation On The Effects Of Human Weight On Intervertebral Disc At Human Lumbar Spine Using Finite Element Analysis” is the result of my own work except as cited in the references.

Signature	: ....
Name	: ....
Date	: ....

ABSTRACT

The population of obesity is expected to increase especially in developed country. The excess human weight compared to normal weight produce extra force to the lumbar spine .Therefore, the increased load originated from the human weight change the mechanical properties of the intervertebral disc which can lead to damage in nucleus pulposus and annulus fibrosus. However, this project intended to investigate the biomechanical effect of human weight on intervertebral disc at human lumbar spine using finite element analysis. The compressive load of 700 N, 900 N and 1100 N with flexion and extension were exerted to the human lumbar spine model that represent the population of normal, overweight and obese. From the result obtained from ABAQUS, the pressure and stress distribution in intervertebral disc increases from normal to obese compressive load. The highest pressure in nucleus pulposus obtained from the analysis was 2.7 MPa during extension motion in L2-L3 lumbar segment under obese compressive load tended to cause disc degeneration disease. Additionally, the highest percentage difference of annulus stress distribution resulted 108.12 % compared to normal weight load during flexion motion in L2-L3 lumbar segment. This increasing weight condition elevated the risk for annulus fibrosus to rupture and damage.

ABSTRAK

Populasi obesiti dijangka akan meningkat terutamanya di negara maju. Keberatan manusia yang berlebihan berbanding dengan keberatan badan biasa menghasilkan daya tambahan di tulang belakang lumbar. Oleh itu, peningkatan beban yang berasal daripada keberatan badan manusia akan mengubah sifat-sifat mekanikal cakera intervertebral yang akan merosakan pulposus nukleus dan anulus fibrosus. Selain itu, tujuan projeck ini adalah untuk menyiasat kesan biomekanik kepelbagaian keberatan manusia pada cakera intervertebral di tulang belakang lumbar manusia menggunakan analisis unsur terhingga. Beban mampatan sebanyak 700 N, 900 N dan 1100 N dengan kombinasi aksi akhiran dan lanjutan telah dikenakan pada model tulang belakang lumbar manusia yang mewakili populasi normal, berat badan berlebihan dan obes. Keputusan yang diperolehi dalam ABAQUS menunjukkan kenaikan taburan tekanan dan tekanan dalam cakera intervertebral dari normal kepada beban mampatan obes. Tekanan tertinggi di pulposus nukleus diperolehi daripada analisis adalah 2.7 MPa semasa lanjutan gerakan dalam L2-L3 segmen lumbar bawah beban mampatan gemuk cenderung untuk menyebabkan penyakit degenerasi cakera. Selain itu, perbezaan peratusan tertinggi agihan tegasan anulus sebanyak 108.12% tinggi berbanding dengan beban berat badan normal semasa akhiran gerakan dalam L2-L3 segmen lumbar. keadaan berat badan yang semakin meningkat ini meninggikan risiko untuk merosakkan and memecahkan anulus fibrosus.

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FEM	Finite element method
LBP	Low back pain
DDD	Degenerated discs disease
IVD	Intervertebral disc
AF	Annulus fibrosus
NP	Nucleus pulposus
L1	The first lumbar vertebra
L2	The second lumbar vertebra
L3	The third lumbar vertebra
L4	The fourth lumbar vertebra
L5	The fifth lumbar vertebra
FEA	Finite element analysis
TDR	Total disc displacement
UTM	Universiti Teknologi Malaysia
FE	Finite element
ROM	Range of motion

IDP	Intradiscal pressure
PLL	Posterior longitudinal ligament
ALL	Anterior longitudinal ligament
LF	Ligamentum flavum
CL	Capsular ligament
ITL	Intertransverse ligament
ISL	Interspinous ligament
SSL	Supraspinous ligament
OA	Osteoarthritis

LIST OF SYMBOLS

E	-	Yong's modulus
v	-	Poisson's ratio
C_1, C_2	-	Material constant characterising the deviataric deformation
M	-	Moment
F	-	Force
d	-	Displacement

CHAPTER 1

INTRODUCTION

1.1 Background

Low back pain (LBP) is one of the public health disorder experienced by human race and it is reported to be 75 % of the population in developed countries experience this musculoskeletal disorder (Viera 2008). Moreover, it threats the health care system and socioeconomics of the countries (Koh et al. 2010). Simplistic, the uncomfortable pain faced by the patient will affect their life quality and daily activities such as climbing, pulling, pushing and lifting or running.

Degeneration Disc Disease (DDD) is declared as the trigger of LBP (Smith et al. 2011). The DDD is originated from the losses of water content and crack condition of IVD tend to reduce its strength to absorb external stresses (Unal et al. 2011). Therefore, the biomechanical behavior changes in IVD maneuver the severity of DDD.

The intervertebral discs (IVD) is a fibrocartilage consist of annulus fibrosus (AF) and a centrally located nucleus pulposes (NP) that can withstand and support the loads from internal and external (O'Connell et al. 2011). Dehydration in the IVDs are known as degenerative disc disease will change the mechanical properties of the IVD and result in structural failure as time goes by (Smith et al. 2011).

Generally, the probability of vertebral to be damaged is depend on the IVD health condition which has the ability to distribute compressive load from human weight (Hussein et al. 2013). However, the attention of this project is to focus on the relationship between the human weights on the biomechanical effect of lumbar spine.

Likewise, the model of the lumbar spine (L1-L5) is constructed using CAD software and the model is simulated by implementing finite element analysis (FEA) which is one of the computational technique to estimate and anticipate the effect of weight on the lumbar spine. The FEA software is worth to be implemented as the results from the simulation can be obtained precisely, faster and economically.

Occasionally, the kinematic motions of the healthy lumbar spine model in flexion, extension, lateral bending, and axial rotation are vitally important to be determined as it will influenced the mechanical properties of the intervertebral disc (Denoziere & Ku 2006). Therefore, this project seems vitally essential as the result obtained are practicable and fabrication of artificial IVD for total disc replacement (TDR) will be more accurate.

1.2 Problem statement

The expanding numbers of obesity and overweight population currently seem to become the norm in the country like China and United State will worsen the severity of the LBP in the nation (Porto et al. 2012; Gordon-Larsen et al. 2014). One of the causes of the LBP is DDD as the mass of water content in IVD decreases via DDD. However, the heavier human weight tends to weaken the strength of disc to withstand the compressive loads and tensile stresses (Silva & Claro 2015).Therefore, it is extremely important to investigate the biomechanical effect of human weight on the disc using FEA of various BMI.

1.3 Objectives

The specific objectives of this project are as follows:

1) To develop a finite element model of the lumbar spine.
2) To investigate the biomechanical effects of IVD at various human weight using FEA.

1.4 Scope

The original three dimensional (3D) model of L1 to L5 lumbar spine was obtained from UTM Faculty of Bioscience and Medical Engineering for simulation purposes. The L1-L5 lumbar spine model was developed and simulated using ABAQUS. The ligaments were neglected in the simulation. The biomechanical effects of normal weight, overweight and obesity were focused on the IVD with intradiscal pressure and von-Mises stress.

CHAPRER 2

LITERATURE REVIEW

2.1 Overview

This chapter describes the background of LBP and human lumbar spine. The development of the FE model of human lumbar spine shows significant effect in future research in mitigating the problems faced by the actual human lumbar spine.

2.2 Spine biomechanics

Biomechanics of the spine define the movement pattern of human spine that causes by force in the body structure. It exposes the functions and principles of the vertebral structures, tissues, ligaments and discs in providing spine stability. Generally, the kinematic and dynamic stability of human spine depend on the motion and muscle. The validation of the mechanical stability will be failed if the muscle or motion is not considered in the human spine simulation and experiments (Bergmark 1989). Therefore, any misunderstanding and misconception of biomechanics of the spine will lead to nervous system damages.

The kinematic motions of the spine can be divided into extension, flexion, and lateral bending as shown in Figure 2.1. This motions are capable to influence the biomechanical effect of the lumbar spine under certain loads (Wong et al. 2003; Panjabi et al. 1994).

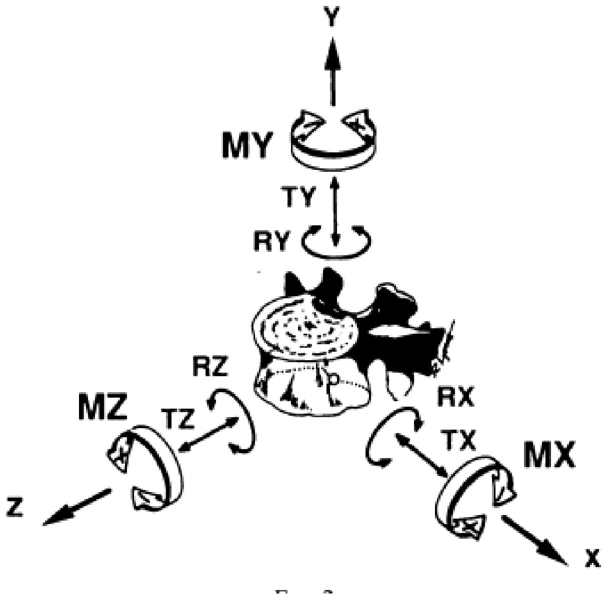

Figure 2.1 The 3D coordinate system used to describe lateral bending (MZ), axial rotation (MY), extension and flexion (MX). Adapted from Panjabi et al. (1994).

2.3 Anatomy of the human spine

The best way to know the function of lumbar spine is to understand the structure and components in the spine. The structure of the human spine can be simplified into five region which is cervical, thoracic, lumbar, sacrum and coccyx region as shown as Figure 2.2.

Figure 2.2 Cervical, thoracic, lumbar, sacrum and coccyx regions of the human spine. Adapted from Aleti & Motaleb (2014).

The cervical spine is comprises of seven vertebrae from C1-C7. Furthermore, the thoracic region is the combination of 12 vertebrae from T1-T12 and the lumbar spine contains 5 vertebrae from L1-L5. Likewise, the region of sacrum and coccyx contain 5 and 4 fused vertebrae. The curve shape and structure of the human spine enhance the mechanical flexibility and act as a shock absorber to support the body (Kurtz & Edidin 2006). This combination of regions ensure the spine is maintained in the stable state during walking, climbing, lifting, pulling, pushing and running.

2.4 Human lumbar spine

The main function of human lumbar spine is to withstand the weight of the upper body and maintain the extensibility and stability of the body in daily activities (Han et al. 2011). Nevertheless, the human lumbar spine is located between the thoracic and sacrum region and comprises of five rigid vertebrae connect with each other via facet joints and IVDs was shown in Figure 2.3. Additionally, the human lumbar spine is made up of vertebral body, posterior element, facet joints, intervertebral discs, ligaments, muscles and motion segments (Kurutz M. 2010).

Figure 2.3 The model of lumbar spine. Adapted from Netter (2006).