CHAPTER I

INTRODUCTION

1.1   Background

Occurrences of knee-related injuries have been steadily increasing over the years, especially in the realm of sports. Ligament injuries are not exclusive to athletes, but they also affect non-athletes as a result of accidents, falls, or even repetitive strain on the knee. Ligaments itself are fibrous bands that connect bones and stabilise joints (Abulhasan & Grey, 2017). They are highly susceptible to injury due to substantial stress exerted during physical activities (Hauser, 2008). The knee joint consists of four ligaments, categorised into two primary groups: cruciate and collateral ligaments. Cruciate ligament injuries in particular are the most frequently reported. There are two main cruciate ligaments: the anterior cruciate ligament (ACL), located at the front, and the posterior cruciate ligament (PCL), positioned at the back. These ligaments cross each other in the middle of the joint, aiding in keeping the knee's surfaces aligned. The ACL prevents forward movement of the tibia, while the PCL controls its backward movement (Choudhuri, 2008). Together, they provide stability and balance to the knee joint, enabling a broad range of motion necessary for various activities.

Knee injuries account for a significant portion of all sports-related injuries, with data showing approximately 41% of such injuries (Sancheti et al., 2010). Additionally, ACL injuries have seen a notable rise in recent years with an incidence rate of 68.6 per 100,000 person-years (Sanders et al., 2016). Cruciate ligament injuries are more likely to occur to women than men (Siegel et al., 2012). In

Indonesia, the number of ACL reconstructions increased by 42% in 2019 compared to 2018, as indicated by implant data (1575 implants in 2018 vs. 2236 in 2019) (Deviandri et al., 2023). Total annual knee injuries have grown significantly over the past two decades, primarily due to an increase in ACL injuries, knee contusions, and PCL injuries among females (Maniar et al., 2022).

Magnetic Resonance Imaging (MRI) is the preferred diagnostic tool for identifying knee ligament injuries in clinical settings. This non-invasive imaging technique uses electromagnetic radiation in a controlled magnetic environment to produce high-resolution cross-sectional images of the body, offering a clear view of internal structures without exposure related risks (Katti et al., 2011). An orthopaedist then decides whether surgical intervention is necessary based on the given image. Within the MRI, focal or diffuse high intensity signals a potential cruciate ligament injury by appearance (Xu et al., 2018). The sensitivity of MRI in diagnosing ACL damage reported to be 95.45% in a study composing of 78 patients, where fat-saturated photon density MRI findings were confirmed through arthroscopy (Zhao et al., 2020). Another study utilising 917 knee MRI from Clinical Hospital Centre Rijeka, Croatia, employed customised deep learning models to classify ACL injuries—categorised as non-injured, partial, and fully ruptured—achieving an accuracy of 96.3% and a sensitivity of 96% using RMSprop optimisation and proton density-weighted MRI sequences (Awan et al., 2021).

Isolated injuries of the PCL are relatively less common by comparison. A prospective analysis found the rate of PCL injury among acute knee injuries in 222 patients to be 38%, with just 3.5% representing isolated injuries (Doerre et al., 2019). A nationwide study in Italy analysed hospital discharge records from 2001

to 2015 reported a low incidence of PCL reconstruction, with an average of 0.46 surgeries per 100,000 inhabitants per year. The highest risk group consisted of young males (median age 30; male-to-female ratio 5.3), and 39.7% of cases involved isolated PCL injuries, while 31.1% were associated with ACL lesions (Longo et al., 2021). Despite MRI's effectiveness in detecting, challenges remain as some injuries are still frequently misdiagnosed. For instance, the ACL tear misdiagnosis rate can reach up to 47% due to factors like synovial hyperplasia and partial volume effects in standard MRI sequences, whereas physical examination has demonstrated higher diagnostic performance for ACL injuries with greater sensitivity (88.67%) and accuracy (90.27%) to MRI 86.79% and 83.33%, respectively (Li et al., 2017; Orlando Júnior et al., 2015).

The grading system for ligament injury is categorised into three levels of severity. Grade 1 involves minor stretching or a low-grade tear with less than 10% of ligament fibres are torn, typically allowing the ligament to maintain joint stability. Grade 2, considered as a medium-grade tear, involves partial tearing of 10% to 50% of the fibres, which results in ligament looseness and some loss of stability. Grade 3 injuries are the most severe, involving more than 50% of fibres torn or a complete tear (Ng, 2011). These injuries often require surgical reconstruction, especially in the case of ACL injuries (Murphy & Knight, 2002). Partial tears of the cruciate ligaments are more difficult to diagnose than complete tears (Ng, 2011). Treatment varies based on the severity of the injury. Minor strains, as seen in low-grade injuries can often be managed conservatively with rest and physical therapy. However, high-grade tears generally require surgery followed by a lengthy rehabilitation process. Recovery can take several months and athletes may not

always regain their pre-injury performance levels. The psychological effects of such injuries are also significant, with studies indicating that up to 42% of affected athletes experience anxiety, depression, or posttraumatic stress disorder (PTSD) (Newcomer & Perna, 2003; Wu et al., 2016).

Considering the current rate of knee injuries and the risk of misdiagnosis, deep learning, particularly Convolutional Neural Network (CNN), offers a promising solution. CNNs can be trained on large datasets of MRI scans to identify knee ligament injuries with a high degree of accuracy. By incorporating CNNs into diagnostic protocols, healthcare providers can potentially reduce diagnostic errors and enhance the overall quality of patient care for those suffering from knee ligament injuries.

1.2   Problem Identification

This study examines whether incorporating both ACL and PCL injury detection in a single multilabel CNN model maintains high diagnostic accuracy or if assessing ACL and PCL injuries separately yields more reliable results using different sets of hyperparameters.

1.3   Problem Limitation

This study is limited to evaluating the accuracy and sensitivity of CNN models in detecting ACL and PCL injuries from T2-weighted MRI scans using a non-saturated proton density dataset. The data consists of 99 patients MRI from SMC Telogorejo Hospital Semarang, with each patient contributing 25 to 30 image sequences. The study was conducted from September 2024 to April 2025 and carried out using a personal laptop in a non-clinical setting (11th Gen Intel® Core™ i5-1135G7 @ 2.40 GHz, 8 GB RAM, Intel® Iris® Xe Graphics with 128 MB

VRAM), which may constrain computational performance and limit the depth or speed of CNN training. The model was trained using a fixed set of regularisation hyperparameters, including stochastic gradient descent (SGD) as the sole optimiser. Ground truth labels relied on manual annotations by radiologists, introducing potential subjectivity and limiting diagnostic certainty compared to arthroscopic confirmation. Additionally, the study focused exclusively on ACL and PCL injuries, excluding other knee structures such as menisci or collateral ligaments, which may reduce its applicability in comprehensive knee assessments.

1.4   Objective of Study

This study aims to optimise the performance of different CNN model hyperparameters based on the specific limitations and to assess whether incorporating ACL alongside PCL injury detection within a single CNN model maintains high metric scores. It is to also assess if analysing each ligament separately yields greater accuracy and sensitivity, based on insights from previous studies. By evaluating these factors, the study seeks to identify the most reliable and effective approach for clinical application in diagnosing ACL and PCL injuries.