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Review: Modelling of meniscus of knee joint during soccer kicking

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Abstract. Knee is a part of the body that located between thigh and shank is one of the most complicated and largest joints in the human body. The common injuries that occur are ligaments, meniscus or bone fracture. During soccer games, the knee is the most critical part that will easily injure due to the shock from an external impact. Torn meniscus is one of the effects. This study will investigate the effect towards the meniscus within the knee joint during soccer ball kicking. We conduct a literary review of 14 journals that discuss the general view of meniscus and also soccer kicking. The selected topics for this review paper are meniscal function, meniscal movement, meniscal tears and also instep kick. As a finding, statistics show that most meniscal tears (73%) occurred in athletes who were soccer players, basketball players or skiers. The tear is frequently happening at the medial side rather than lateral side with a percentage of 70%.

1. Introduction

Knee is a part of the body that located between thigh and shank is one of the most complicated and largest joint in human body. The knee has to support nearly the whole of human's weight, so that it is easy for the knee to get injured. The common injuries that occur are ligaments, meniscus or bone fracture which are internal part of the knee. For soccer games, knee is the most critical part that will easily injure due to the shock from an external impact. Torn meniscus is one of the effects. This study will learn about the effect towards the meniscus within the knee joint during soccer kicking.

2. Methodology

The method use for this paper is by reviewing 14 journals that discussed about the general view of meniscus and also soccer kicking. The selected topics for this review paper are meniscal function, meniscal movement, meniscal tears and also instep kick. Each topic will be discussed deeply reviewed from the selected journal.

3. Meniscal Function

Out of 15 journals, nine journals discussed about the function of meniscus deeply. The meniscus acts an important role towards the knee in order to protect the joint between the femur and tibia. Meniscus is two crescent shapes that located between the femur and tibia, which its function discussed a lot by researchers. The main function of meniscus is to distribute the load across the joint between femur and tibia. Other than that, meniscus is also act as stabilizer between the joint, joint lubrication and so on.



Many literatures discussed about its main function that is distributing load. By distributing the load across the joint, this will ensure the stability of the joint. This will result the stress experienced by the joint been decreased. Figure 1 below shows the different between the knee with meniscus and without meniscus.

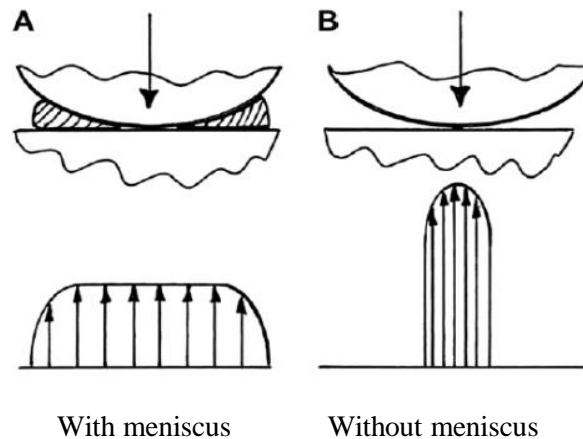


Figure 1. Differences between the knee with meniscus and without meniscus. Taken from *I.D. McDermott et al.*

The common description of the menisci is that they are semi-lunar fibrocartilagenous disks, whose main function is to increase the congruency of the tibiofemoral joint, thereby decreasing the stress in the joint through an increase in the contact area [1]. Since the meniscus is a viscoelastic material, it will tend to compress when the load is applied. As the femur and tibia is moving, the meniscus is also will move, so that the congruency of the joint can be maintained.

When the meniscus move from its original shape, it shows that force is being transferred across the meniscus body. This is called the hoop stresses that act within the meniscus body. The compression force across the knee, as it is transmitted from the femur through the meniscus to the tibia, causes tension along the circumferential collagen fibres within the meniscal tissues [1]. From what been said by I.D. McDermott in his literature about the development of hoop stress within the meniscus body, it is a result from a net resultant force that generated when load is applied. The wedge shape of meniscus after being loaded will make it to extrude from the joint. In order to prevent the meniscus from extrude more, hoop stresses is developed.

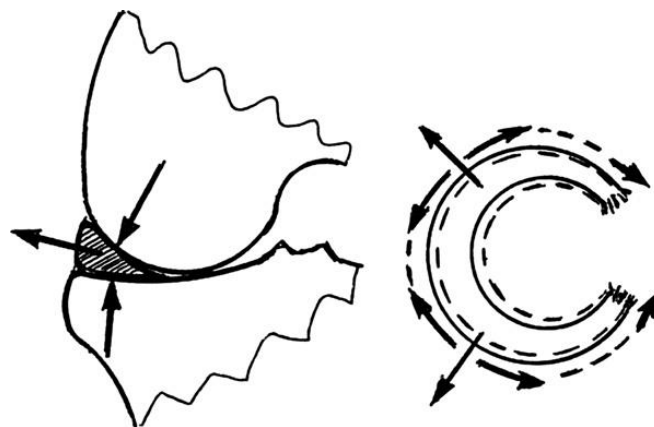


Figure 2. Conversion of axial load into meniscal hoop stresses. Taken from *Ian D. McDermott et al*

4. Meniscal Movement

Meniscus of the knee is having viscoelastic properties that are described as a combination or mixture of solid and also fluid components. Viscoelastic and elastic has their own properties. For elastic material, Viscoelastic and elastic material is having a different meaning and properties. In an elastic material, the energy used to deform the material is equal to the integral of the force deformation curve [2]. That is mean, when loading and unloading process, there will be no energy loss or any energy absorption. This is opposite with the viscoelastic condition. When loading and unloading process, the energy between those two works will not the same. Fithian et al. said that the energy loss phenomenon is due to the movement of fluid and/or the rearranging of molecule structure of the tissue itself. Since the meniscus is having fluid structure in its cross section, the meniscal water content could be extruded either by compression or by direct application of a pressure differential [1]. This will result with the displacement or deformation of meniscus. P.S. Walker et al. said that the meniscus function is to maintain the congruency of the femur and tibia joint, hence, the meniscus will carry about 40% to 70% of the load across knee. When load is applied, force distribution will go through the femur and the meniscus will experienced the force. The fluid component of meniscus will slowly to extrude depends on its permeability and the viscosity of fluid. V. Vedi et al have done experimental setup by testing subject's knee joint to determine the meniscal movement through an arc of flexion-extension while weight bearing. The result state that the menisci do move posteriorly as the knee flexes and the lateral meniscus did move more compared to the medial meniscus [3]. From the results, it shows that the movement of the meniscus during the knee- flexion is to ensure the maximum congruency of the joint and also the articulating surfaces in order to avoid it from injury when having load.

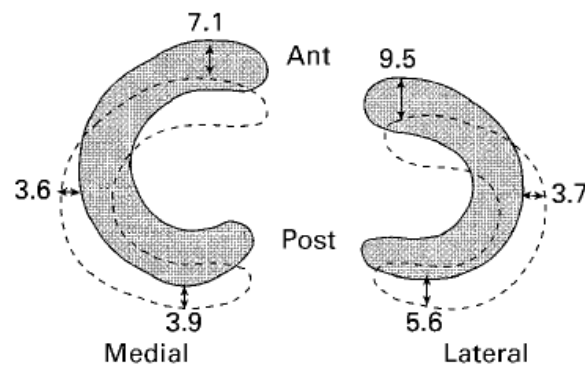


Figure 3 (a). Diagram shows the mean movement in each meniscus with weight bearing. Taken from V. Vedi et al. 1995.

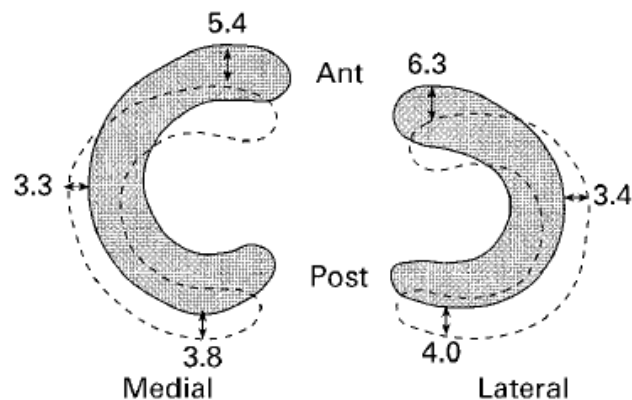


Figure 3(b). Diagram shows the mean movement in each meniscus with unloaded knee. Taken from V. Vedi et al. 1995.

5. Meniscal Tears

Knee meniscus is a two semicircular pad that can be found between the joint of upper leg bone (femur) and lower leg bone (tibia). It is become the function of meniscus to be an effective load transmission and also shock absorber, so that the joint congruency can be enhanced. All material that is continuously loaded will have defect on its body. Same goes with the meniscus. The common defects that always occur is tear. Meniscal tears can happen to everyone without notice. Whether the age is young or old, everybody have a chance to get it depends on their lifestyle. At the young age, meniscal tears are caused by trauma in which happen while they are doing activity. In case, their knee is pivoted or twisted while they are doing activity, the meniscus can be torn. For old age, meniscus tears are a common thing for them. It is because the fluid structure within the meniscus will degenerate as their age is increased [15].

There are many types of meniscus tears that can be classified. Meniscal tears can be classified according to their location, shape, size, and stability. The classified tears are vertical longitudinal, oblique or called as parrot beaked, displace or called bucket handle, degenerative, transverse, horizontal or complex. Out of those tears, the most common tears that always occur are vertical longitudinal and the oblique tears. Greis et al. said that, about 81% of the meniscus tears are parrot beak or longitudinal tears affecting more often the medial meniscus. Figure 4 below shows a certain pattern of tears that happen at the knee meniscus.

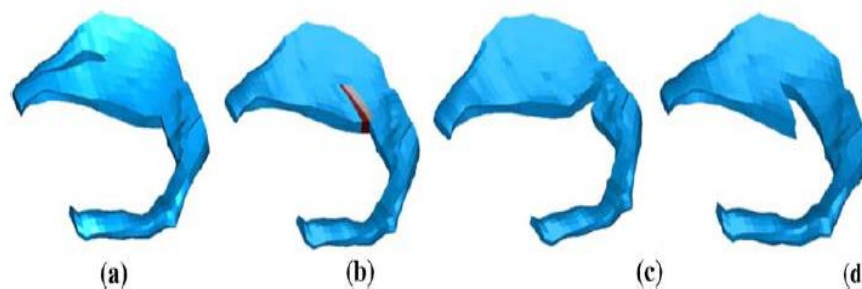


Figure 4. Patterns of meniscal tear: a) longitudinal; b) oblique; c) transverse; d) parrot beak. Taken from *E. Pena et al. 2005*.

Once the meniscus torn, surgical is the best way to prevent any complication happens towards the knee joint. If not, the continuous knee motion and continuous load applied towards the meniscus can worsen the original tear. The surgical way that is one of the best is meniscectomy. Meniscectomy is a step to alter the shape of meniscus or remove the tear part of the meniscus. There are also different types of meniscectomy which are longitudinal, radial, oblique and total. After meniscectomy is done towards the torn meniscus, it will result with effect towards the joint of femur and tibia. LeRoux and Setton said that meniscectomy dramatically alter the pattern of static load transmission of the knee joint. This is because the fluid structure within the meniscus is being altered and the way of meniscus distributing the load will be different with the healthy meniscus. Hoop stresses are lost when a radial tear occurs or a segmental meniscectomy is performed; the load bearing condition become similar to that after meniscectomy [5]. Figure 5 shows a difference of load distributing between a healthy meniscus and also meniscus after meniscectomy.

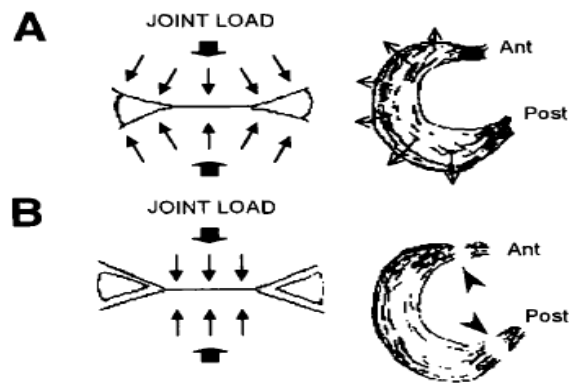


Figure 5. Difference of load distributing between **A.** healthy meniscus and also **B.** meniscus after meniscectomy. Taken from *J.M. Lee 2000*.

Out of four types of meniscectomy, the total meniscectomy is the least type that applied in the surgery. This is because the effect afterwards is worse than others. Total meniscectomy will result with articular wear after a certain years. This is because there is one missing meniscus after the total meniscectomy. Fithian et al. said that, several researchers have reported higher stresses and a decrease in shock absorbing capability after total meniscectomy. That shows the important of meniscus as a load transmission between the joint.

After the meniscectomy, the rehabilitation program is important so that the healing process is smoothly done. Forces that occur during knee motion potentially could distract the meniscal repair and disrupt healing [6]. Basically, the meniscal repair should aim to maintain the structure of the meniscus which is circumferential. This is to maintain the function of meniscus which is load transmission so that the joint surface is not subjected to the excessive stresses.

6. Instep Kick

From the selected journal, the literature is discussed more on instep kick which is the common kick that player use in a soccer game. Instep kick also has become the most widely studied for a soccer kicking [7]. A study about the kicking technique can be important if we want to enhance our understanding regarding the biomechanics of soccer. Other than that, by studying about the biomechanics of kicking, coaching process can be assisted [7]. Figure 6 below shows the kinematic of instep kicking.

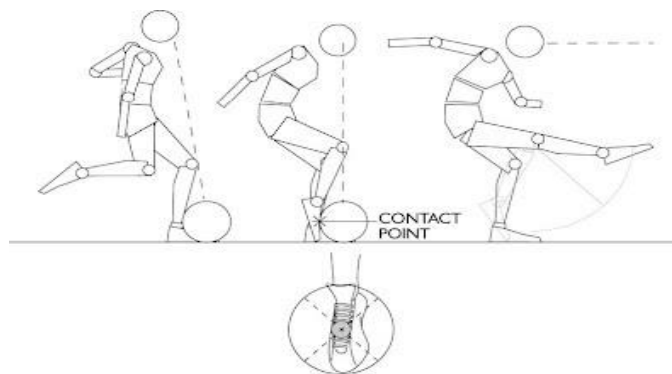


Figure 6. Kinematic of instep kicking. Taken from <http://www.ayso26.org/soccer>

As been discussed by a lot of researchers about the instep kicking, there are a few factors that can ensure the successful of that kicking which are distance of the kick from the ball, type of kick used, the air resistance and also the technique used. All of these can be taken as a biomechanical analysis. Other than the factors above, the foot to ball interaction is also important. This is including the speed of feet before the kicking is done. The higher the speed of the foot before impact, the shorter the football contact and the highest the ball speed [7]. The best output of instep kicking is depends on the highest velocity of ball after being kicked. In order to get the maximal velocity of ball after being kicked is by applying the highest velocity on the foot before the impact. Kicking with running approach demonstrates higher ball speed values compared with static approach kicks. This is because, the velocity of the foot is increasing since the player applying running approach before kicking. Table below shows the velocity of the foot and coefficient of restitution at impact between the foot and the ball.

Table 1. Summaries of the journal

No	Author of Journal	Method			Topic			
		Experimental	FEA	Theory	Meniscal Function	Meniscal Movement	Meniscal Tears	Soccer
1	Yunfeng Niu et al. (2012)		√		√			
2	T.M. Guess et al. (2010)		√		√	√		
3	J.M. Lee et al. (2000)			√	√			
4	J.R. Meakin et al (2002)	√			√			
5	D.P. Richards et al (2008)	√					√	
6	E. Pena et al. (2005)		√		√		√	
7	I.D. McDermott et al. (2008)			√	√	√		
8	A.A. Allen et al. (1995)			√	√			
9	A.R. Ismail et al. (2010)	√						√
10	S. Andrews et al. (2011)			√	√			
11	A. Lees et al (2010)			√				√
12	E. Pena et al. (2005)	√			√			
13	E. Kellis et al. (2007)			√				√
14	V. Vedi et al (1999)	√				√		

Table 2. The velocity of the foot and coefficient of restitution at impact

	Foot Speed (ms^{-1})		Coefficient of Restitution	
	Min	Max	Min	Max
Preferred Leg	16.1	20.3	0.46	0.68
Non-Preferred Leg	15.5	18.6	0.32	0.66

Based on the pie chart above, it is represented the percentage of injury breakdown by body part for soccer game. There are thirteen body parts that may be injured while playing the soccer game which are thigh, feet, knees, ankles, hips, back, neck, wrists, head, abdomen, elbow, forearms and lastly is shoulders. The factor that may cause the injury may come from external impact towards the body part or from the pivoting or twisting of body parts. From what being discussed in this paper, which is the knee, it is the part that becomes top three commonly injured in a soccer game with 14.6%. It is proven that the knee is a part that can injured easily while player is playing the soccer.

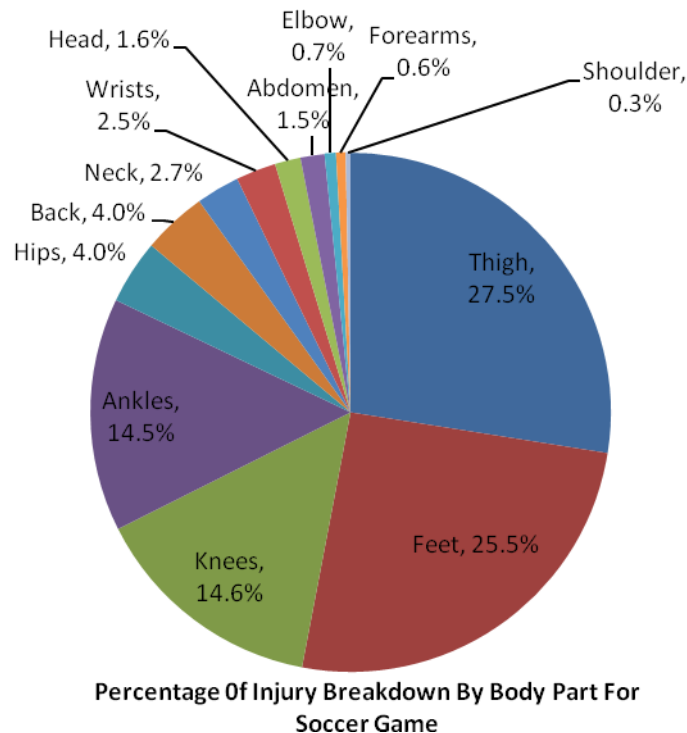


Figure 7. Percentage of injury breakdown by body part for soccer game.

7. Conclusion

Overall, this paper is reviewing the selected 14 journals in study of the knee meniscus and the soccer related. From what can be conclude about the meniscus, it is the small internal part that has big function towards our body. The primary function of the meniscus as the load transmission is to prevent the excessive stress and maintain the congruency to the femur and tibia joint. Based on the pie chart above, it is shows that the knee is in top 3 parts that easily injured in a soccer games and the torn meniscus is one of the injury. Statistical state that the most meniscal tears which is 73% occurred in athletes who were soccer players, basketball players or skiers. The torn is frequently happening at the medial side rather than lateral side with a percentage of 70% [18]. The statistic shows that the injury from playing soccer may injured the meniscus part easily. Related to the study, by choosing either preferred or non-preferred leg will result with different force towards the ball before kicking. This force will directly acting towards the meniscus that located between the joint of the knee.

Acknowledgments

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