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Check the Nature and Measure the Amount of Joint Fluid: A Review

Greenwood Quaintance*

Department of Orthopedic Surgery, Mayo Clinicgrid.66875.3a, Rochester, Minnesota, USA

Corresponding author:
Greenwood Quaintance, Department of Orthopedic Surgery, Mayo Clinicgrid.66875.3a, Rochester, Minnesota, USA. E-mail: greenwood_q@gmail.com

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Abstract

Arthritis is inflammation of one or more joints in the body. Its main symptoms are pain and stiffness in the affected area. Accompanying pain in the knee joint is caused by a hardening fluid in the joint called synovial fluid. Its kinetics determine the compressive load and the characteristics of the articular cartilage. This article highlights the properties of synovial fluid and explores the mechanisms of synovial fluid lubrication for age-related changes while considering gender differences. In addition, this article reviews existing studies that have been done on deep learning-based auto-sensing and acoustic monitoring on joint health and response to measurement using novel methods such as electromechanical resistance. resistance (EMI) of the piezoelectric torsion probe.

Keywords: Translation; Arthritis; Synovial aging and sex; Measure synovial fluid; Piezoelectric pickup; Joint lubricant

Introduction

Arthritis is one of the major health problems facing the world. The US Centers for Disease Control and Prevention predicts that there will be more than 67 million arthritis patients by 2030 [1]. Arthritis is inflammation of one or more joints in the body. Its main symptoms are pain and stiffness in the affected area. The disease tends to manifest mainly in the elderly and specific treatment measures are needed to control the spread of the disease. Accompanying pain in the knee joint is caused by a hardening fluid in the joint called synovial fluid. Its kinetics determine the compressive load and the characteristics of the articular cartilage. In humans and animals, markers derived from synovial fluid are commonly indicated in patients with joint disorders, the most common of which are rheumatoid arthritis and osteoarthritis. By closely monitoring a single indexed joint by carefully examining the synovial fluid volume, total biomarkers in the joint can be easily obtained [2]. To arrive at such an estimate of total synovial fluid volume, there are several common tests such as blood tests, pathology, related radiological tests such as X-rays and MRIs as well as ultrasound, and microscopic tomography. calculation and control of the joint fluid. In case the patient is in the early stages of the disease, just basic blood tests and X-rays are enough. However, people with a more severe form of the problem need more rigorous testing, such as magnetic resonance imaging, joint fluid testing, or even ultrasound of the affected area [3].

It should be noted that the standard viscometers used in laboratories for testing are often large and expensive machines that cannot measure continuously. Furthermore, the fluid is manually aspirated from the joint and is not compatible with the real environment [4]. This means that such synovial fluid tests are never 100% correct [5]. So, what could be the most viable and alternative solution? The most encouraging capabilities are provided by resonant sensors such as shear thickness mode (TSM) and piezoelectric cantilever. Moreover, nowadays, the use of electromechanical impedance method (EMI) has become quite common for structural health monitoring (SHM) [6].

This article highlights the properties of synovial fluid and explores the mechanisms of synovial fluid lubrication for age-related changes while considering gender differences. In addition, this article reviews existing studies that have been performed on deep learning-based auto-sensing and acoustic monitoring on joint health and response to measurement using novel methods such as electromechanical resistance. resistance (EMI) of the piezoelectric torsion probe.

Synovial fluid analysis

The term synovia refers to its resemblance to the white part of the egg [7]. Synovial fluid can be explained as the collection of fluid that remains confined to specific joint spaces. It is an ultrafiltrate of plasma and is mainly composed of hyaluronan, lubricin, proteinase, collagenase and prostaglandin. Such fluid is physiological, acting as a lubricant of the articular space of the articular cartilage. It also diffuses essential nutrients to nearby structures such as cartilage, cartilage, and lips [6]. Synovial fluid resides in different parts of the human body such as knees, lumbar joints, ankle joints, shoulder joints, hip joints and other small joints. Figure 1 highlights the presence of fluid in the human body. Joint cartilage contains an inner lining membrane called the synovial membrane, which is responsible for producing synovial fluid for the joint. The synovial membrane contains small folds that manage pressure inside the joint and joint movement [1]. Since synovial fluid surrounds joints and lubricates them, its analysis will uncover the source of joint pain and swelling. The operation of the knee joint system was examined through the properties of the synovial fluid [8]. The presence of synovial fluid in joints was first studied by Hippocrates' Greek text, "Of the Places of Man". A Roman physician also makes an earlier reference to synovialism in his text, "On the Functions of the Parts of the Human Body". The estimated amount of synovial fluid in the knee joint ranges from 0.5 to 2 ml. [first]. Figure 2 shows the presence of synovial fluid in the knee.

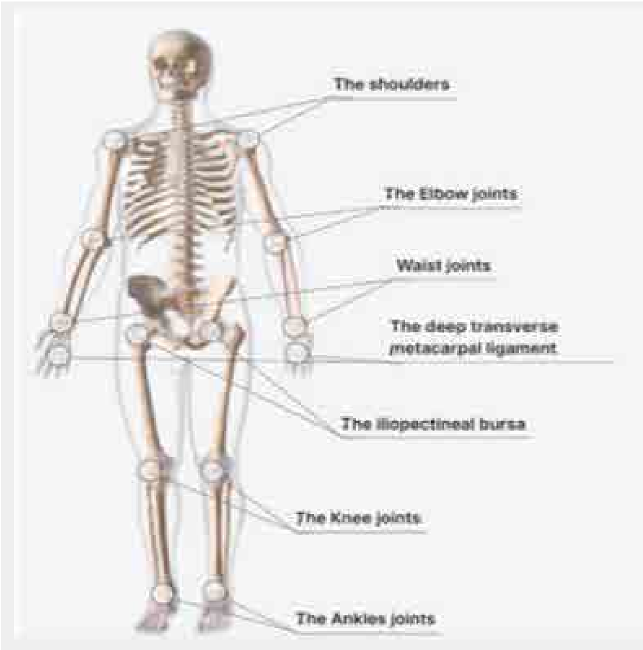

Figure 1: Major Synovial Fluids in human body.

In their research paper, Prekasan & Saju [1] explain that synovial fluid is composed of hyaluronic acid and is identical to plasma with a protein content of 2%. It is used for natural lubrication of elbow and knee joints. It contains surfactant phospholipid, proteoglycan 4 and hyaluronic acid. Chondrocytes that secrete these lubricants are synovial and articular cartilage cells. The synovial spaces in the joint are responsible for the concentration of synovial fluid. A deficiency in the lubrication system contributes to the erosion of articular cartilage, creating arthritis. The molecular concentration of hyaluronic acid is 1-4 mg/ml, that of proteoglycan is 0.05-0.35 mg/ml and that of active phosphorus lipid is 0.1 mg/ml. Synovial fluid interacts with joint surfaces in relative motion to reduce the effects of friction during joint movement.

Joint fluid plays a diagnostic role in detecting potential causes of joint pain. Specific conditions recognized for synovial fluid use include septic arthritis, bleeding joints, autoimmune disorders,

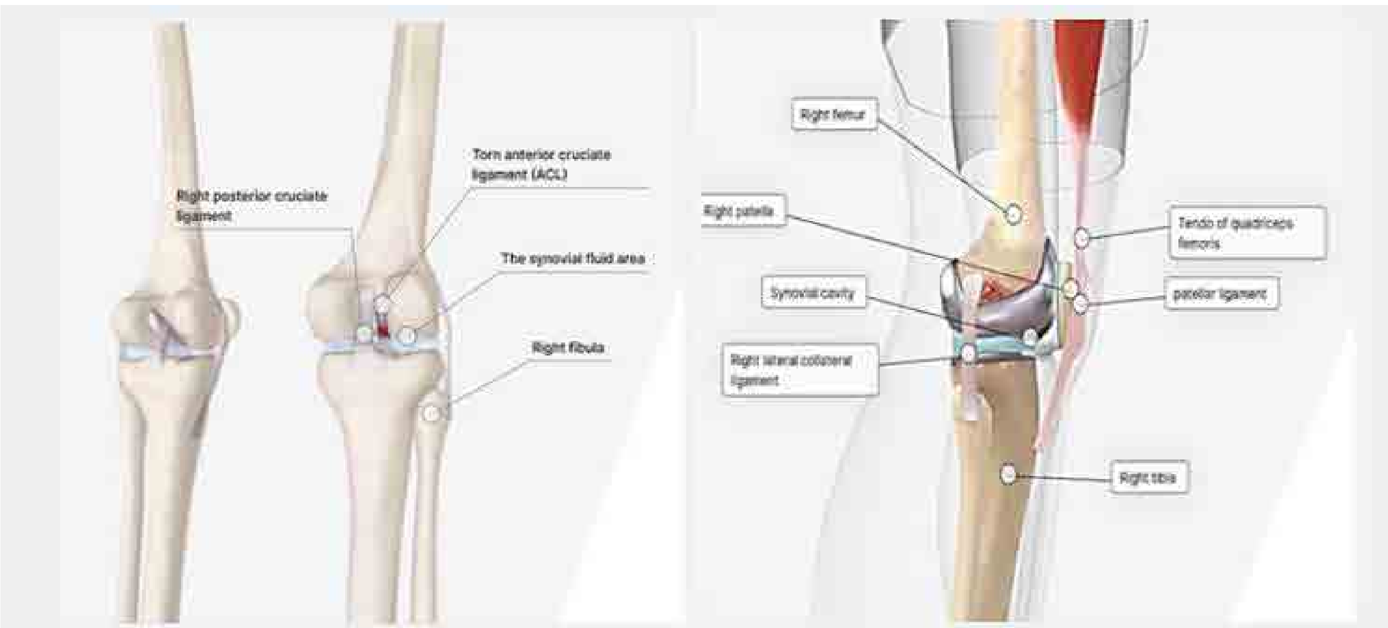

Figure 2: A and B The Structure of Knee Joints.

and pseudogout. The testing process consists of three categories - microscopic evaluation, gross assessment and chemical analysis. Changes in the concentration of synovial fluid in the joints lead to joint pain, bleeding, and infectious diseases [8].

Seidman & Limaiem [6] state that when assessing the overall synovial fluid, physicians consider the fluid's viscosity, clarity, volume, and color. This helps identify symptoms of an infection in the joint. During a chemical test of the synovial fluid, specialists check the uric acid levels in the joints. This is done through glucose tests, protein tests and lactose tests which can explain the reason for joint infection and other health ailments in the patient. Microscopic examination of the synovial fluid is aided by lens examination for infectious material. During the microscopic examination, doctors check for cultured bacteria that have accumulated in the joint by examining the individual's immune system (WBC). Gram stain is also calculated and used to determine the cause of infection, factors that lead to changes in synovial fluid in the body, and treatment requirements.

Research focuses on synovial fluid and joint health

Knee joint health issues are of great interest to medical professionals and researchers. There are many ongoing investigations into the knee health of researchers working in the electrical field. They focus on electrical devices that measure and determine the level of knee health, particularly synovial and joint health. Humans have to bear many different loads on joints when moving, especially the knee joint. Such loads on the joints contribute to tissue damage due to the development of degenerative pathological conditions and cartilage damage [9]. These conditions are called osteoarthritis (OA). Spain & Cheneler [9] studied the sound monitoring of joint health. Researchers have identified classification methods that demonstrate the severity of knee injuries. Lawrence and Kellgren's system identified radiographic evidence of osteoarthritis concentrations and scaled it from 0 to 4. However, the information obtained from radiographic evidence was not sufficient to identify cartilage damage. because this method has low inter-observer precision. The researchers also looked at other methods that effectively quantify the development of osteoarthritis, including non-radiation and non-invasive methods. They identified clinical parameters and developed different therapies that are effective in limiting and reducing osteoarthritis. Changes in knee sound under load and motion conditions are an indication of structural changes in the knee joint and are associated with osteoarthritis. The researchers also looked at joint vibrations and sounds coming from the knee joint. Monitoring knee joints for osteoarthritis has allowed researchers to demonstrate the joint's need for synovial fluid. On the other hand, Morea et al. [7] reviewed the rheological properties of synovial fluid and explained treatment options for osteoarthritis. They discussed the lubricating properties of synovial fluid and linked it to an electrolyte solution that promotes joint mobility. They identified the interactions between the different components of the synovial fluid and related it to the fluid's complex rheological properties. Their analysis of rheumatoid arthritis and osteoarthritis demonstrated the remarkable efficacy of synovial fluid and its lubricating capacity. They argued that cases of viscous addition increased the concentration of the synovial fluid, affecting its molecular weight and the fluid's rheological properties. They also reviewed the rheological and macroscopic properties of the synovial fluid and noted challenges with its clinical efficacy and viscosity. The rheological properties of synovial fluid describe in detail the fluid viscosity required for the lubrication of joint tissues for proper movement.

Mairan et al. [10] explores the mechanism by which synovial fluid prolongs the life of joints. It has been noted many times in this article that the basic function of synovial fluid is to lubricate the joints. The composition of the synovial fluid includes active phospholipids, hyaluronic acid and surfactant proteins. Mairan et al. [10] also identified its other protein components such as the serum protein gamma globulin and the human serum protein that helps the synovial fluid lubricate the joints. They identified the biology of synovial fluid and reviewed current knowledge of lubrication. The promising use of synovial fluid has allowed researchers to determine its ability to fight osteoarthritis. The main goals of their study were to determine the role of proteins in prosthetic lubrication, the impact of physical variables on prosthetic lubrication, and the optimal combination of materials for the prosthesis. fake part. They tested the synovial fluid abrasion mechanism to determine the lubricating properties of the prosthesis. Synovial fluids have been studied under biological conditions to identify several pseudo-components and also discussed the superior lubricating properties of the fluid. It lubricates the knee and elbow joints and prevents the accumulation of uric acid in the joints. Synovial fluid artificial testing has demonstrated the exact chemical composition of various components and their lubricating mechanism to develop an efficient lubricating mechanism.

Liao et al. [11] evaluated pathological changes in fluids to develop numerical understanding in their study. They studied the roughness of the cartilage surface to understand the characteristics of the synovial fluid. The researchers focused on degenerative joint conditions caused by the gap between synovial fluid and cartilage. First, they assessed the topography of the cartilage surface in healthy and osteoarticular conditions. They developed the link between the stages of health and disease through a numerical method that took into account the transverse and longitudinal roughness of the cartilage surface. Calibration based on existing experimental synovial fluid data provided constitutive equations for synovial fluid viscosity. The results showed that the cartilage surface reduced permeability by about 30-60%. They tested spatial permeability for discrete cartilage surface dimensions. The testing process results in decreased and increased permeability of voids on different cartilage surfaces. The air permeability of the space is the result of the early ultrafiltration of the fluid in the joint tissues. The permeability of the cartilage surface cleft is strongly influenced by pathological synovial fluid. The surface of the OA cartilage increases the size of the permeability of the space up to several hundred times. The differential pressure always remains below 106 Pa/m, resulting in ultrafiltration of the fluid in the tissues. Joint function is strongly affected by the changing osteoarthritis condition and the gap in contact with the cartilage.

Age-related changes and sex differences in synovial fluid

As the human body ages, it affects changes in the level of development at different stages and in different locations in the body. The term aging refers to the various physiological changes that the body undergoes from adulthood until death. Bones in the body are remodeled throughout life as old bone tissue is replaced by new tissue. This systematized remodeling process ensures a balance between bone resorption and formation, thereby maintaining skeletal integrity. Like most things, this balance also changes as people age [12]. The bones that are not in direct contact at the joints should be listed here. Indeed, the articular cartilage that lines the joints acts as a cushion. The joints are also protected by synovial membranes while the synovial fluid acts as a lubricant to ensure constant joint movement. However, synovial fluid decreases as people age, cartilage becomes thinner - leading to stiffening around joints causing them to stiffen, worse still, ligaments become shorter with age and lose their properties. flexibility, which also causes stiffness [13].

It can be reasonably expected that when these changes occur, they often lead to a decline in biological functions, causing corresponding mental changes, such as psychological and behavioral changes. Because. Sometimes such variation is obvious, while other times it may not be so noticeable. As bones age, their mineral content also begins to deplete. This makes people more susceptible to osteoporosis, in which bones lose density, become more brittle and therefore more prone to fractures. As people age, the rate of bone resorption by osteoclasts becomes greater than the rate of bone formation. Since these multinucleated cells include mitochondria and lysosomes that aid in bone resorption, bone weakens when this process is reversed [12]. With all the references to synovial fluid in this article, at this point it's important to explain the important role it plays in joint health. It has been noted that this fluid lubricates the joints to ensure smooth movement. In addition, healthy joints contain large amounts of high molar mass hyaluronic acid (HA) molecules in the synovial fluid, ensuring perfect viscosity as a lubricant. As people age, the size of HA molecules decreases, reducing their ability to act as buffer and lubricant carriers [8,14].

Uesaka et al. [15] investigated sex differences and age-related changes in the HA and chondroitin sulfate (CS) isoforms in normal synovial fluid. This study has shown that age and gender profoundly affect the tissues of the knee joint, leading to osteoarthritis. They determined the levels of HA and CS isomers in normal synovial fluid to test the effects of age and sex on its concentration. They tested a population sample consisting of healthy subjects of different ages who provided data on the effect of age on lubricant levels for the knee joint. 187 healthy volunteers were tested between the ages of 14 and 89. Research results show that most of the components of synovial fluid are negatively correlated with the age factor. There were no sex-related differences in synovial fluid concentrations. However, the CS isomer in normal synovial fluid is significantly affected by sex-related differences. Affected concentrations also vary between women and men.

Temple-Wong et al. [16], in their study, analyzed the size distribution and concentration of hyaluronan in human knee synovial fluid. They identified variations in synovial fluid with cartilage degeneration and age-related factors. Potential endpoints identified during cartilage wear for a normal knee joint are an alternative to synovial fluid intake and lubricant content. They established a specific correlation between synovial fluid and age factors. They analyzed synovial fluid from donors (ages 23 to 91) who did not have osteoarthritis. The researchers also studied healthy communities to determine the molecular weight of hyaluronan and the protein components of synovial fluid. Concentrations were tested against the left and right knees of those sampled. Bland-Altman and T-test were performed to check synovial fluid concentration. Regression analysis was then performed to determine the relationship between each biochemical component. The results showed that at a later age, cartilage wear was related to the quality of synovial fluid and the content of hyaluronan in the joints. The study authors determined concentrations of all biochemical components of the synovial fluid. Healthy joints contain a protein concentration range of 2.5–7 MDa (–9.4 %/decade), 1–2.5 MDa (–11.3 %/decade), 0.5–1 MDa (–12.5%/decade) and 0.03–0.5 MDa (–13.0%/decade). They concluded that hyaluronan levels were more closely related to age than joint level.

June et al. [5] performed a synovial fluid viscosity test to diagnose periarticular joint infection (PAI). The main objective of this study was to identify an accurate test method that provides authentic results for PJI testing. The researchers examined 45 patients with PJI - PJI (n 1⁄4 15), aseptic error correction (n 1⁄4 15), and primary joint replacement (n 1⁄4 15). The researchers argued that the viscosity of synovial fluid changes in patients with periarticular joint infections. They determined the sensitivity of the viscosity difference to develop an accurate test framework. They used the criteria for musculoskeletal infection to determine how viscous synovial fluid was. They also measured each patient's plasma

D-dimer, C-reactive protein and erythrocyte sedimentation rates. The results indicated that the viscosity of synovial fluid was 0.0011, which was significantly lower in patients with PJI than in those without this infection. The level of synovial fluid viscosity exceeded plasma CRP, ESR and D-dimer, with a sensitivity of 93.33% and a specificity of 66.67%.

Conclusion

From reading existing research and our insights derived from it, this article offers several solutions to problems related to synovial fluid. The basic role of synovial fluid is to lubricate the joints. It is composed of powerful phospholipids, hyaluronic acid and surfactant proteins. Evaluation of rheumatoid arthritis and irritant osteoarthritis conditions revealed an important presence of synovial fluid and its ability to lubricate joints. Viscos complement events add the center of gravity of the synovial fluid, affecting its atomic weight and the fluid's rheological properties. Such properties of synovial fluid are expressed in its thickness; however, there is no known procedure for consistent phase analysis of synovial fluid. This imbalance of intracellular fluid has been shown to cause many health problems and its deliberation is disrupted inside the joints. Each joint in the joint capsule is bound to synovial fluid as a carrier oil for the joint. Also, this synovial fluid is called synovial membrane because it looks like protein. The main job of this fluid is to lubricate the joints and provide additional linear motion. Such lubrication helps ensure smooth movement and reduces stress on joints. Age has a significant effect on the volume of synovial fluid in the body. This study concludes that there are new methods to measure synovial fluid volume. One such method discussed is the piezoelectric method which is characterized by miniaturization, small energy use, self-excitation and self-exploration qualities. Another procedure listed in this article is the concept of bioelectrical impedance, in which synovial fluid measurements are taken for rapid results that can ensure quality care for the patient. have joint mobility problems.

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