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ORIGINAL

EFFECT OF HIP OSTEOARTHRITIS ON TOTAL HIP REPLACEMENT FAILURE AND REVISION: A FOCUSED STUDY ON ATHLETIC POPULATIONS

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ABSTRACT

Objective: This study aims to analyze the specific impact of hip osteoarthritis on the failure and subsequent revision of total hip replacements, with a particular focus on athletic populations. Considering the unique biomechanical demands and higher physical activity levels of athletes, the study seeks to understand how these factors influence post-surgical outcomes in cases of hip osteoarthritis. **Methods:** The research involved collecting and analyzing data from athletes who had undergone total hip replacement surgeries due to hip osteoarthritis. Patient demographics such as age, gender, and the severity of the disease were recorded. The study performed a detailed correlation analysis to evaluate the influence of hip osteoarthritis on the failure rates of total hip replacements in this specific group. It particularly focused on hip failure caused by arthritis, cement fixation failure in aseptic arthritis cases, and cemented hip failure due to primary inflammation. **Results:** The findings indicate that in athletic populations, hip osteoarthritis is significantly correlated with higher failure rates after total hip replacement, with an influence rate of 30.64%. This rate is notably higher compared to general population statistics, underscoring the unique challenges faced in treating athletes. The study also found a notable correlation between the type and severity of arthritis and the failure modes of hip replacements, including issues related to cement fixation. **Conclusion:** This study highlights the significant impact of hip osteoarthritis on the failure of total

hip replacements in athletes, a group that typically places higher physical demands on hip joints post-surgery. The correlation between arthritis severity and replacement failure underscores the need for tailored surgical and rehabilitation approaches for athletic individuals. These findings stress the importance of considering the specific biomechanical and lifestyle needs of athletes in managing hip osteoarthritis and planning total hip replacement surgeries.

KEYWORDS: bone cement; Aseptic arthritis; total hip replacement; loosening failure

1. INTRODUCTION

Total hip replacement (THR) surgery stands as a pivotal intervention for individuals suffering from severe hip joint damage, predominantly due to osteoarthritis. While THR is generally successful across various populations, its efficacy and durability can vary considerably, especially among athletes. This study focuses on exploring the impact of hip osteoarthritis on the failure and revision rates of THR, particularly in the athletic population, a group characterized by unique biomechanical stresses and lifestyle demands (Aroganam et al., 2019).

Hip osteoarthritis, characterized by the degeneration of joint cartilage and the underlying bone, is a leading cause of chronic pain and mobility issues. It's one of the primary reasons for undergoing THR, a procedure aimed at alleviating pain and restoring joint functionality. However, the scenario becomes more complex when considering athletes. Athletes place unusually high demands on their hip joints due to intense training and competition, potentially influencing both the immediate outcomes and long-term success of hip replacements (Beckner et al., 2022).

The athletic population presents a distinct challenge in the context of THR. Factors such as the intensity of physical activity, type of sports involved, and the athlete's age and gender play crucial roles in determining the post-surgical success. These factors influence not just the surgical approach and choice of prosthesis but also postoperative rehabilitation and long-term joint care (Cheng et al., 2023; Habay et al., 2023).

In this study, we delve into the specifics of how hip osteoarthritis affects THR in athletes. The research encompasses a comprehensive review of patient demographics (age, gender), severity of osteoarthritis, and athletic activity levels. Special attention is given to the type of sports activity and the level of performance, as these are key factors in understanding the biomechanical demands placed on the hip joint post-replacement (Ginevičienė et al., 2022; Hu et al., 2022). Furthermore, the study examines the failure mechanisms unique to THRs in athletes. These include an in-depth analysis of issues such as

cement fixation failure, which is particularly relevant in aseptic arthritis cases, and failures due to primary inflammation. Given that athletes may experience different failure modes or accelerated wear and tear of the prosthetic joint, understanding these mechanisms is vital for tailoring surgical and post-surgical interventions.

2. Methods and Design

2.1 Design.

This paper collected a total of 14973 surgical patients admitted to a Hospital from 2016 to 2021. There were 6169 patients (41.2%) accepted joint replacement, including 2550 hip arthroplasty patients, 2108 knee arthroplasty patients, 608 spine arthroplasty patients, 413 ankle arthroplasty patients and 490 shoulder arthroplasty patients. Figure 1 shows the proportion of all the cases.

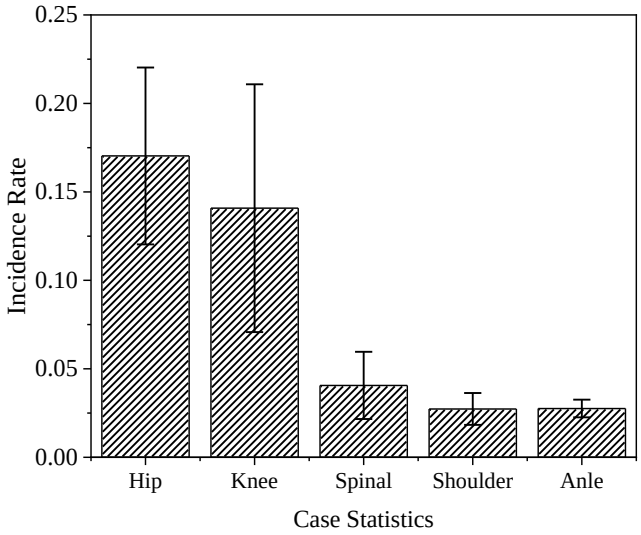

Figure 1: Joints disease rates

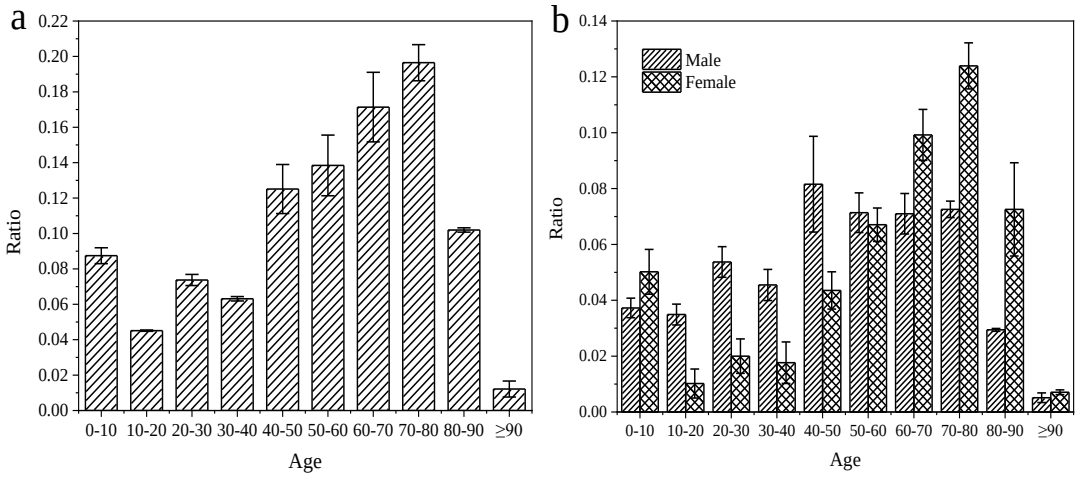

Figure 2: Patients' Percentage of THA：(a) Age；(b) Gender

2.2 Measures

This paper collected the results of arthritis in 60-75% of patients with hip joint. The experiment performed linear regression on the large number of data and processed them by the least squares method. The measurement data were expressed as mean ± standard deviation. The T-test was used for significance analysis of difference. The analysis of variance (ANOVA) in statistical analysis software SPSS 20.0 was used to analyze the significance, and $P<0.05$ was considered as that the variance was statistically significant

2.3 Analysis

The hip joint disease patients in this study included 1269 male patients (49.8%) and 1281 female patients (50.2%). According to Figure 1, hip replacement was the most common disease, including 2195 cases of primary replacement and 355 cases of revision. There was also a gender difference in hip joint patients, including 1269 male patients (49.8%) and 1281 female patients (50.2%). It can be seen from Figure 2 that there are gender differences in artificial hip replacement at different ages. Among the people before the age of 50, the proportion of male patients is higher than that of female patients, while after the age of 60, the proportion of female patients is significantly higher than that of male patients. Because female's physiological characteristics lead to the loss of important calcium elements from bone tissue, the female patients with THA keeps increasing.

3. Results and Analysis

Osteoarthritis is the main problem of hip replacement. It leads to a certain degree of joint degeneration, chondromalacia and other bone and joint inflammations. The known causes include primary inflammatory arthritis such as rheumatoid arthritis and ankylosing spondylitis, acromegaly and a variety of other metabolic diseases that are prone to congenital hip dislocation and slip epiphyseal resulting in joint deformities. It is mainly manifested as joint pain and inflexibilities, and even a certain degree of hip and knee function loss. Therefore, most patients often use joint replacement to improve joint function and relieve pain. The incidence rate of this disease is about 10% among Chinese people aged 65 years and above (Jagim et al., 2023). At present, there are few researches on the effect of arthritis on hip replacement failure. This paper carries out research and analysis on this topic.

3.1 Correlation between arthritis and hip failure

According to the statistics of clinical symptoms of the first and revised artificial hip joint (Table 1), the symptoms of the patients firstly accepted hip replacement was mainly manifested in femoral head necrosis, osteoporosis, hypertension, arthritis and other diseases. Since the human body is an organic

organism, hip replacement is caused by a variety of factors. Human bone tissue activity has a life cycle. Body weight, poor lifestyle and loss of calcium ions cause the femur to be unable to support human physiological activities.

Table 1: Incidence of disease affecting hip replacement

PRIMARY SYMPTOMS	RATIO	REVISION SYMPTOMS	RATIO
HEAD NECROSIS	20.75%	Dislocation	44.92%
OSTEOPOROSIS	12.82%	Looseness	25.71%
HYPERTENSION	15.14%	Bone fracture	8.19%
ARTHRITIS	12.27%	Tumor fibro cellular	12.71%
NECK FRACTURE	24.82%	Debonding	4.80%
DIABETES	5.76%	Osteoma	3.67%

As shown in Figure 3, the incidence of arthritis increased with age. The incidence of the disease peaked at 0.119 in the 70-79 age group, and then decreased significantly in the 80-89 age group and then leveled off. Through correlation analysis, the results of arthritis on THA replacement rate showed that preoperative arthritis had a great influence on THA replacement. Pearson correlation coefficient was 0.932 (significance was 0.002<0.05), so arthritis is very important for preoperative THA risk warning. However, arthritis had small effect on revision rate after initial replacement, but had great significance. Although the association is much smaller than that before replacement, the risk of arthritis remains, and it is still important for patients to maintain their arthritis treatment for postoperative recovery.

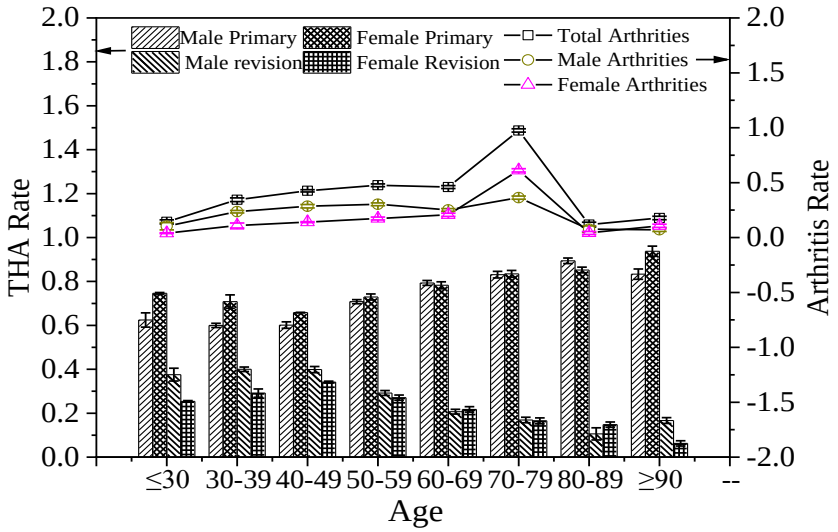

Figure 3: Replacement ratio diagram of arthritis-THA

3.2 Effect of aseptic arthritis on cemented fixation failure

In this paper, the patient's synovial fluid around the bone cement fragments was extracted as shown in Figure 4, and the active cells of the sample were processed by immuno histochemical staining (SABC method).

PIPS-2020 ultra-definition pathological graph analysis system was used for imaging processing. It was found that osteoclasts clustered on the surface of bone cement, as shown in Figure 5, and the osteoclasts evolved from macrophages phagocytosed the globular debris, which proved the previous literatures.

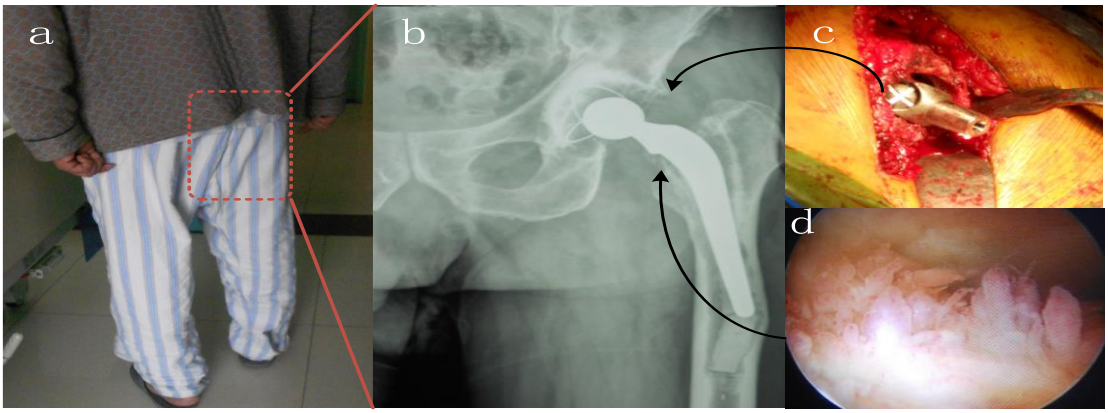

Figure 4: A patient with hip revision: (a) Patient's standing posture; (b) X-rays; (c) Extraction of the prosthesis stem; (d) Synovial fluid. Joint fluid of a hip revision patient

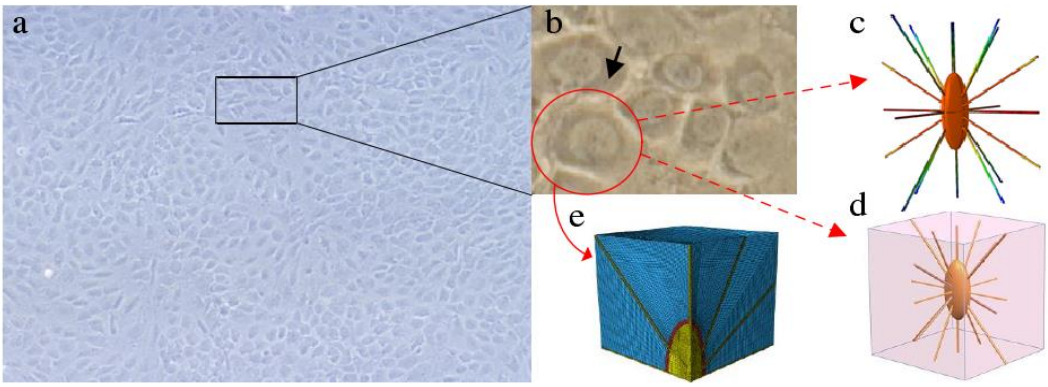

Figure 5: Osteoclast in cemented hip: (a) Osteoclast aggregation；(b) a single cell image；(c) Devoured debris；(d)and (e) 3D sketch of osteoclasts

Studies had found that osteolysis originated from macrophages and was mainly activated by the RANK/RANKL/OPG system, which induced the transformation of macrophages into osteoclasts and finally achieved osteolysis. Among them, RANKL was the core factor in tumor necrosis system, which could not only induce the transformation of macrophages into osteoclasts, but also further promote the proliferation, differentiation and maturation of osteoclasts.

RANKL, MMP-9 and TIMP-1 are abundant in bone cement hip prostheses (Park et al., 2023). MMP-9 is the most important enzyme with the largest relative molecular weight in the MMPs family, and it's degraded by mainly uses gelatin, IV, V, VI, type X collagen and elastic fiber as substrates. MMP-9 could not only participate in the degradation of collagen fibers in bone, but also directly induce the activation of osteoclasts. TIMP-1 is a glycoprotein, which can not only bind with MMP-9 to block its activity, but also bind with

inactive MMP-9 proenzyme to prevent its activation. It can specifically bind to activated MMP-9 or inactive MMP-9 proenzyme at the carboxyl-terminal of the catalytic region to form a firm complex. It is a natural inhibitor of MMP-9 (Purcell et al., 2019). RANKL could not only reduce the expression of TIMP-1 in osteoclasts, but also promoted the activation of MMP-9 precursors and lowered the ratio of TIMP-1 to MMP-9. In case of imbalance, it promoted the expression of MMP-9 in osteoclasts. If RANKL was over-expressed, the enhanced activity of MMPs exceeds the action range of TIMPs, breaking the balance system between MMPs and TIMPs, and leading to the occurrence of aseptic loosening of the prosthesis (Satyaninrum et al., 2023).

The study found that there was indeed a large amount of RANKL, MMP-9 and TIMP-1 in the surrounding membrane tissue of aseptically loose prostheses. It played an important role in the process of aseptic loosening of joint prosthesis. Polyethylene, titanium alloy and bone cement particles could all induce macrophages to produce various kinds of inflammation, stimulate osteolysis, lead to the aggregation of osteoclasts in the body to the surrounding bone of the prosthesis, promote the excessive proliferation and activation of osteoclasts, cause the rapid dissolution of the surrounding bone of the prosthesis, and eventually lead to the occurrence of aseptic loosening of the joint prosthesis (Varillas-Delgado et al., 2022). What's more, the more serious the inflammatory reaction was due to the dense micro-cracks and the high degree of abrasive aggregation, the more serious the degree of osteolysis was. Further studies showed that different shapes of wear particles induced different degrees of inflammatory response. For example, spherical particles were more likely to be phagocytosed by macrophages than long strip particles when the number was the same, which was more likely to induce inflammatory response. Therefore, it can be proved that the size, concentration, composition, surface morphology and physical and chemical properties of wear particles are closely related to the occurrence of aseptic loosening (Spyrou, 2019).

3.3 Influence of primary inflammation on cement hip failure

Mechanical stress and rheumatic inflammation were widely considered to be the two mechanisms underlying osteoarthritis of femur. Hip arthritis was an osteoarthritic disease of articular cartilage degeneration or bone structure change due to long-term uneven weight bearing on the hip surface. The main initial pathology symptoms occur in the femoral head, including pain (radiating to the knee), swelling, joint effusion, cartilage wear, bone spur hyperplasia, joint deformation, and limited rotation and extension of the hip. Widespread osteoarthritis after hip surgery was controversial. However, the studies based on clinical series showed that although the diseased part is removed after hip replacement and the incidence rate is low, there was still residual inflammation in the femoral shaft and knee, which was easy to lead to secondary revision (Wee et al., 2018).

3.4 Factors analysis for affecting arthritis

Osteoarthritis is the most common form of arthritis in the world and a major cause of disability for middle-aged and elderly people (Wang et al., 2023; Yadav & Reddy, 2023). Some studies had found that the main factors affecting joint inflammation are obesity, enzymes and hormones, gender and lymph nodes.

3.4.1 Obesity causes arthritis

Some studies found through animal tests that excessive thigh obesity could lead to the increase of femoral neck forward inclination, thus increasing the possibility of osteoarthritis (Bernstein, 1965; Eccles & Wigfield, 2020). This study found that the correlation between BMI and femur anterior inclination was 0.456, with a significance of 0.304, and the correlation between two variables in female was 0.644, with a significance of 0.119. The correlation between the two variables was stronger in women than in men, which confirmed the above view. In addition, there are differences between obese adults and children and normal people in hip abduction angle, gait coordination, stride length and stability, indicating that obesity had an impact on gait and lead to hip inflammatory degeneration. Therefore, the influence of obesity on bone and joint degeneration was related to biomechanics (Fogle, 2017).

There is a correlation between BMI and hip osteoarthritis in patients recovering from hip arthroplasty. The greater the BMI, the worse the postoperative pain relief and functional efficacy. The mechanism was mainly related to the increase of force per unit area, poor stability, increased wear, loosening and subsidence. Therefore, weight loss can help to reduce the load per unit area of bone and joint, increase the nerve response speed, and delay the process of bone and articular surface destruction. Meanwhile, tobacco, alcohol and other bad habits and moderate hypertension could also increase the risk of hip osteoarthritis in obese patients (Jabbarov, 2020).

3.4.2 Effects of enzymes and hormones on arthritis

The research hadn’t found out the biomechanics-related mechanisms of obesity leading to degenerative joint disease through active enzymes in arthritis. The influence of circulating steroid concentration on male osteoarthritis (Jung & Won, 2018). They extracted dehydroepiandrosterone sulfate, androstenedione, testosterone, estradiol, androgen-binding glucosan and androgen-binding globulin, and studied their impact on arthritis. Besides, low plasma androstenedione concentrations increase the risk of osteoarthritis in overweight and obese hip replacement patients. In human osteocytes, androstenedione is an important precursor to produce T, E2 and Ag in non-gonadal tissues, which is conducive to the maintenance of long bone growth. Androstenedione can promote the increase of bone mineral density in femoral

diaphysis and diaphysis region (SADEGHI et al., 2019).

3.4.3 Influence of gender on arthritis

In case of same BMI, female had a stronger relationship with hip replacement than male. The BMI of males was 30.00-32.49 kg/m^2 and that of females was 27.50-29.99 kg/m2. Median pain duration and imaging severity of male were similar to that of female at the same mean age, but female lateral femur diseases were slightly more severe than internal and concentric cartilage injuries, and female suffered more frequent concentric cartilage injuries than male (Lindquist, 2017).

3.4.4 The relationship between lymph nodes and arthritis

Heberden's nodes were an independent risk factor for hip osteoarthritis. There was a statistically significant association between Heberden's nodes and the presence of hip osteoarthritis (Matthews et al., 2018). The number of patients with hip osteoarthritis diagnosed with one or more identified Heberden's nodes was approximately 1.6 times that of patients without Heberden's nodes, and Heberden's nodes were more prevalent in female (53%) than male (19%), and the association between hip osteoarthritis and the presence of Heberden's nodes was stronger in male than female (Nation, 2019). The risk of hip arthritis was 3.2 times higher in one in third of patients with the highest BMI and identified lymph nodes than that in the lowest one in third of patients without Heberden's nodes BMI distribution. Association between Heberden's nodes, hip injury, and the risk of unilateral or bilateral osteoarthritis (Puglisi et al., 2017).

4. Discussion

This paper analyzed the failure causes of replacement by investigating the clinical data of patients with bone cement revision, and found that joint inflammation was significantly correlated with postoperative failure, and the impact rate on failure was 30.64%. After loosening of the interface between stem-bone cement, the micro dynamic mechanism generated debris to stimulate the proliferation of osteoclasts (RANKL, MMP-9 and TIMP-1) so as to accelerate osteolysis, and the ball debris was more easily swallowed by macrophages than the bar debris. The two aspects promoted decline of bone mineral density and bone strength, activated primary arthritis and induced aseptic inflammation, accelerated osteopathy and weakened the stem-cement fixation. The vicious cycle affected the loosening of the interface and the sinking of the stem, which eventually lead to sterility failure. This study systematically treated and analyzed the fixation failure of bone cement by combining pathological correlation statistical analysis, failure extract, medical imaging and active cell immuno histochemical staining (SABC), and found that a large number of osteoclasts clustered on the surface of bone cement, which proved

the previous literatures.

The trend of bone density in Chinese people shows that BMD gradually rises and reaches its peak before the age of 30, and then gradually declines. This is mainly because the physiological development of Chinese people is gradually completed before 30. Exercise and nutrition intake strengthen bone and all physiological functions reach their peak. After the age of 40, Chinese people generally appear bone loss phenomenon, namely bone loss period. This is mainly the result of many reasons in work and life. Therefore, doctors often advise Chinese people to strengthen nutrition and exercise to strengthen bone strength and muscle and reduce bone loading. After the age of 50, the difference in bone mineral density decrease between male and female gradually increases, which is mainly due to the influence of biological characteristics of male and female. The phenomenon of bone loss is more significant in menstruating and postmenopausal women. Men, on the other hand, can improve bone strength and muscle strength through nutrition and exercise. Doctors strongly recommend that Chinese people start to reasonably supplement nutrition from the age of 40, especially calcium. Especially after the age of 50, people shall further supplement nutrition and strengthen osteopenia loss. It is explained from the side that female bone mineral density is sensitive to THA replacement rate and has strong correlation. At present, there is no systematic health program suitable for Chinese people to reduce osteoporosis, so this aspect needs to be improved.

5. Conclusion

This study offers crucial insights into the relationship between hip osteoarthritis and the failure of total hip replacements, specifically within the athletic population. The key finding that athletes exhibit a higher rate of hip replacement failure (30.64%) compared to general populations highlights the unique challenges this group faces in the post-surgical phase. This elevated failure rate is indicative of the additional stresses that athletic activities place on surgically replaced hip joints. The correlation between the severity of hip osteoarthritis and the failure modes of hip replacements in athletes emphasizes the need for a more nuanced approach in both surgical and postoperative management. For athletes, who typically return to high levels of physical activity post-surgery, it is crucial to tailor the type of hip replacement, the surgical technique, and the rehabilitation process to withstand higher biomechanical demands. Furthermore, this study underscores the importance of thorough pre-surgical planning and patient education, especially for athletes. Understanding the specific risks and modifying training and activity regimens post-surgery are essential to prolong the lifespan of the hip replacement and ensure a successful return to athletic activities.

In conclusion, the findings of this study call for a heightened awareness

and a customized approach in treating athletes with hip osteoarthritis undergoing total hip replacement. Surgeons and rehabilitation professionals should consider the distinct biomechanical demands and lifestyle factors of athletic patients to optimize surgical outcomes and minimize the risk of implant failure. This targeted approach is key to improving the long-term quality of life and athletic performance for this unique patient demographic.

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