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Aseptic Femoral Head Osteonecrosis in the Katanga Mining Province in Southeast of Democratic Republic of the Congo

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Abstract

Aseptic osteonecrosis of the femoral head is defined as the death of bone cells in the femoral epiphysis due to an interruption of blood supply. Most cases are linked to trauma, but non-traumatic cases also occur and can be associated with several known risk factors. This study aims to describe these risk factors identified in the former Katanga province, a region with significant mining activity. **Method and Patients:** This is a descriptive cross-sectional study conducted over a seven-year period (2017-2024), including all cases of aseptic osteonecrosis of the femoral head diagnosed in the orthopedic department of Medpark Clinic in Lubumbashi. The investigation of risk factors was based on the analysis of sociodemographic, clinical, radiological, and biological data. **Results:** Our study included a total of 110 patients with a mean age of 47.5 years. Among them, there were 46 women (41.82%) and 64 men (58.18%). Twenty-five patients (27.5%) reported a family history of osteonecrosis, and 24% were diagnosed with sickle cell disease. Chronic alcoholism was noted in 14 patients (12.73%), while diabetes was present in 8 (7.2%). Four patients (3.64%) were obese, and three were HIV-positive (2.72%). The use of non-steroidal anti-inflammatory drugs (NSAIDs) was common, and prolonged corticosteroid use was documented in 5 patients (4.5%). Abnormally high cholesterol levels were found in 26 patients (23.6%). One patient had gout, and

two suffered from acute rheumatic fever (1.8%). Regarding inflammatory markers, C-reactive protein levels and erythrocyte sedimentation rates were within normal limits for almost all patients. Electrolyte levels and phosphocalcic profiles showed no abnormalities. Furthermore, 33 patients (30%) did not exhibit any of the previously mentioned risk factors. Most of these patients lived in the regions of Kolwezi, Likasi, and Lubumbashi. Among this group, 25 patients reported performing physically demanding labor, particularly in mining operations. **Conclusion:** Our study highlighted well-known risk factors for osteonecrosis of the femoral head (ONFH). However, it also identified a significant number of cases without any identifiable risk factors, classified as idiopathic. Among these cases, some patients engaged in intense physical labor, often linked to mining exposure.

Keywords

Osteonecrosis, Mining, Katanga

1. Introduction

Aseptic osteonecrosis is the death of bone cells resulting from an interruption in blood supply to the bone [1]. Although this condition primarily affects the femoral head, it can occur in any part of the skeleton. The majority of cases of osteonecrosis of the femoral head (ONFH) are linked to trauma, such as fractures or dislocations, which disrupt the blood flow to the bone. However, non-traumatic cases also occur, and their causes are often less well understood. These cases may be associated with various risk factors, including prolonged corticosteroid use, chronic alcoholism, metabolic disorders, coagulation abnormalities, sickle cell disease, or lupus. In some instances, no specific cause is identified, making idiopathic osteonecrosis particularly enigmatic and challenging to prevent [2] [3].

In mining environments, specific risk factors may also contribute to the development of aseptic osteonecrosis. Repetitive physical stresses, such as carrying heavy loads and traversing rugged terrains, impose significant pressure on the lower limbs [4], potentially impairing the blood supply to the femoral head. Additionally, exposure to toxic substances or chemicals, including heavy metals commonly found in mining areas, can induce metabolic changes that may compromise bone health.

This study aims to describe the risk factors for aseptic osteonecrosis of the femoral head in the former Katanga province, located within the copper belt in southeastern Democratic Republic of the Congo.

2. Method

The study was conducted at Medpark Clinic, a specialized orthopedic and trauma center in Lubumbashi, the largest city in the region. This clinic provides care to orthopedic patients from various surrounding towns and districts, many of which

are located within the cobalt belt of the former Katanga mining province.

The Katanga Province, in the southeastern part of the Democratic Republic of the Congo (DRC), is historically and economically renowned as a major mining hub. It boasts abundant natural resources, particularly strategic minerals such as copper, cobalt, uranium, zinc, and other valuable metals. The region hosts numerous international and local mining companies, with operations ranging from large-scale industrial mining to small-scale artisanal activities.

This is a cross-sectional descriptive study carried out over seven years (2017-2024), including all cases of aseptic osteonecrosis of the femoral head diagnosed at the clinic during this period. The diagnosis was confirmed using medical imaging (X-rays, CT scans, MRI). Cases of infectious or traumatic origin were excluded. The identification of risk factors was based on an analysis of sociodemographic, clinical, radiological, and biological data (complete blood count, erythrocyte sedimentation rate test, hemoglobin electrophoresis, retroviral serology, cholesterol testing, triglyceride testing, uric acid testing, blood glucose testing).

Data collection was both retrospective and prospective, including patients recruited during a free consultation campaign organized by the clinic in April 2023.

Data processing was performed using EPI Info 7 software. The study adhered to ethical principles for scientific research and received approval from the ethics committee of the University of Lubumbashi. We defined heavy labor as the activity of patients who reported regularly carrying heavy loads or walking and climbing hills almost daily, regardless of the weight of the loads or the distance covered. Furthermore, the duration of exposure to heavy metals was considered for patients living within 2 kilometers of mining sites for a period of at least 5 years.

3. Patients

Table 1. Distribution of patients according to sex and side of osteonecrosis.

Sex	Bilateral	Right	Left	Total
F	13	14	19	46
%	28.2%	30.4%	41.3%	100%
M	13	24	27	64
%	20.3%	37.5%	42.1%	100%
TOTAL	26	38	46	110
%	23.6%	34.5%	41.8%	100%

The study included a total of 110 patients with an average age of 47.5 years, ranging from 4 to 78 years. There were 46 women (41.8%) and 64 men (58%) (Table 1). The condition was located in the right hip for 38 patients (34.5%), the left hip for 46 patients (41.8%), and bilaterally for 26 patients (23.6%) (Table 1). The onset of the disease, primarily marked by hip pain, had an average duration of 4 years, ranging from 30 days to 20 years. Pain was mainly reported in the groin (68.46%), greater trochanter (44.8%), and buttocks (19.5%), with projection to the thigh in 35.68% of cases. Additionally, 85.9% of patients reported walking pain,

and 82.5% experienced limping.

Limb shortening was observed in 74% of patients, with an average reduction of 2 cm. According to the Arlet and Ficat classification [5], the radiographic stages of patients were distributed as follows: Stage I (7.2%), Stage II (14.5%), Stage III (20%), and Stage IV (58.1%) (Table 2).

Table 2. Distribution of patients according to the radiological stage of Alert and Ficat.

Stage	Frequency	Percentage
1 (no lesion)	8	7.2%
2 (flattening)	16	14.5%
3 (fragmentation)	22	20.0%
4 (osteoarthritis)	64	**50.1%**
Total	110	100.0%

4. Results (Table 3 and Figure 1)

Table 3. Distribution of patients according to risk factors.

Risk Factor	Frequency	%
Alcoholism	14	12.7%
Asthma	1	0.91%
None	33	30.00%
Corticosteroid therapy	5	4.5%
Diabetes	8	7.2%
Sickle-cell anemia	25	23.6%
Smokers	4	3.6%
Drop	1	0.9%
Hiv	2	1.8%
HTA	6	5.4%
Obesity	4	3.6%
Rheumatism	2	1.8%
TBC	4	3.6%

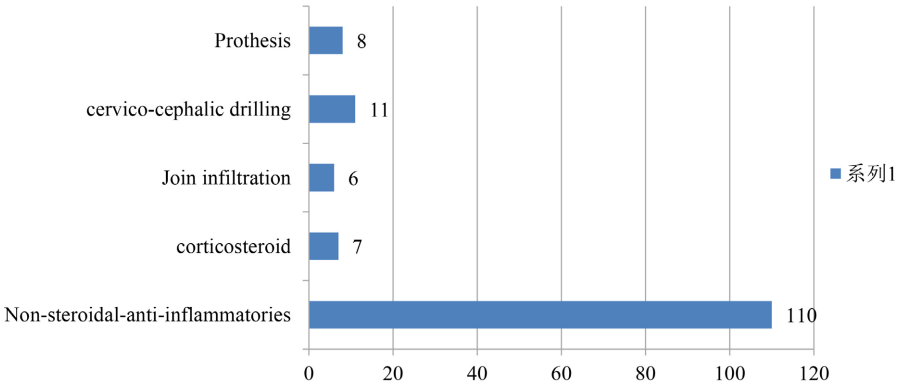

Figure 1. Distribution of patients according to previous treatment.

In our study, 23.6% of patients were affected by sickle cell disease. This group included most adolescent patients, with an average age of 20 years (range: 4 - 49 years). One of these patients, a 30-year-old woman, exhibited multiple disease locations, affecting both femoral and humeral epiphyses. Among non-sickle cell patients, five reported a family history of femoral head osteonecrosis (Figure 2). In this group, two patients from the same family had bilateral ONTF, with one case identified incidentally during a pelvic X-ray. Their mother also suffered from osteonecrosis due to bilateral hip dysplasia (Figure 3).

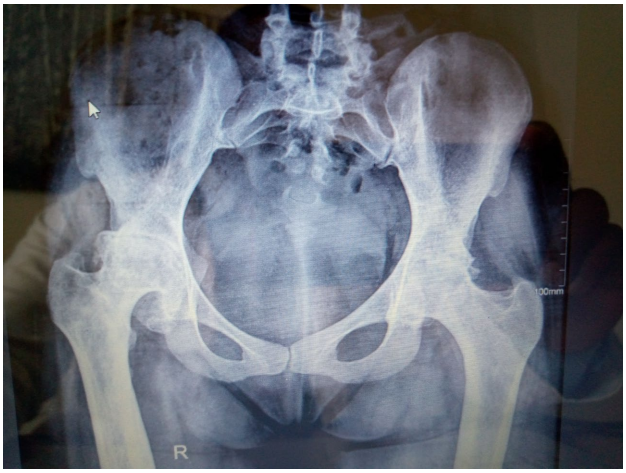

Figure 2. Bilateral femoral head osteonecrosis in a 34-year-old sickle cell patient.

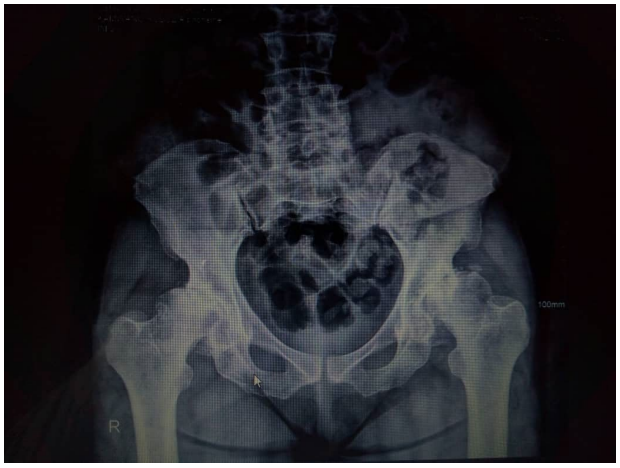

Figure 3. Bilateral femoral head osteonecrosis due to hip dysplasia in a 53-year-old patient.

Chronic alcoholism was associated with osteonecrosis in 14 patients (12.7%). Diabetes was found in 8 patients (7.6%), primarily adults aged 47 - 77. One diabetic patient had undergone a left thigh amputation three years earlier due to gangrene. Another patient with bilateral femoral head osteonecrosis also had severe degenerative lumbar spine arthritis, which required spinal fusion surgery.

Four patients (3.6%) were obese, with an average body mass index of 32. One of them had severe bilateral gonarthrosis and a history of six intra-articular

injections. None of the patients presented deep vein thrombosis in the lower limbs. Three patients were HIV-positive (Figure 4), including one with pulmonary tuberculosis and another with Pott's disease. No pregnant women were included in the study.

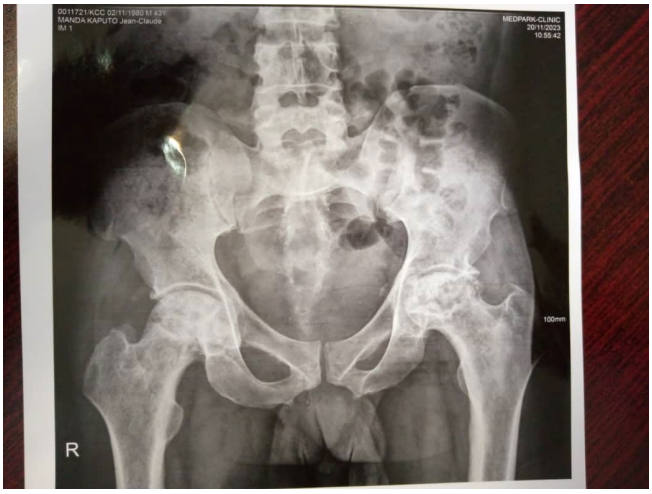

Figure 4. Bilateral femoral head osteonecrosis in an HIV-positive patient.

Regarding medication-induced causes, nearly all patients had taken nonsteroidal anti-inflammatory drugs, often combined with various analgesics. Prolonged corticosteroid use was documented in 5 patients (4.5%), including one asthmatic patient and two HIV-positive patients also receiving antiretroviral therapy.

Radiological examination identified two atypical cases: a 53-year-old woman with bilateral hip dysplasia and a 13-year-old overweight adolescent with neglected slipped capital femoral epiphysis of the right hip (Figure 5). Additionally, 18 patients (16.3%) in our series had associated lumbar disc disease.

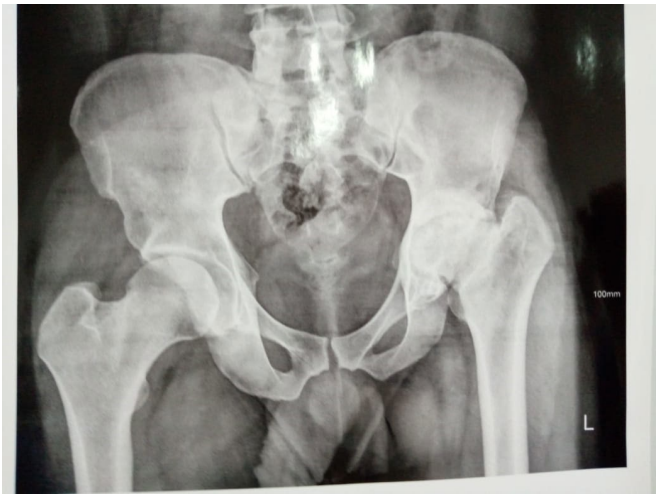

Figure 5. Neglected left cephalic epiphysiolysis.

Biological tests showed elevated cholesterol levels in 26 patients (23.63%),

including all obese patients and half of the chronic alcohol users. One 43-year-old patient had gout, and two had acute rheumatic fever, confirmed by elevated uric acid and rheumatoid factor levels.

Inflammatory markers, including C-reactive protein and erythrocyte sedimentation rate, were normal in most cases. Electrolyte and phosphocalcium profiles revealed no abnormalities.

Finally, 33 patients (30%) exhibited no identified risk factors. Most of these patients resided in or near mining areas in Kolwezi, Likasi, and Lubumbashi (**Table 4**). Within this group, 25 patients (22.7%) reported engaging in physically demanding labor, primarily as miners. These activities were predominantly performed by men, representing 90% of this subgroup.

Table 4. Distribution of patients according to residence and mining occupation.

	Work in a mine		
Sites	**No**	**Yes**	**Total**
Autres	1	0	1
Kambove	3	1	4
Kasumbalesa	2	0	2
Kipushi	3	2	5
Kolwezi	14	9	23
Likasi	6	2	8
Lubumbashi	56	11	67
TOTAL	85	25	110

5. Discussion

Aseptic femoral head osteonecrosis (ONFH) accounts for about 3% of hip diseases. In the United States, around 30,000 new cases are diagnosed annually, contributing to approximately 10% of total hip replacement cases [6]. In the United Kingdom, its incidence is estimated between 1.4 and 3.0 cases per 100,000 people per year [7]. In sub-Saharan Africa, while precise data on the prevalence of ONFH is not available, it is evident that it is a leading cause of secondary coxarthrosis [8].

ONFH primarily affects individuals aged 20 to 50 years [2], a trend confirmed by our study, as well as the predominance of males, with a male-to-female ratio of 1.4. This gender difference may be attributed to lifestyle factors or professions predominantly occupied by men, often involving physically intense activities that may contribute to the development of ONFH.

ONFH can be either bilateral or unilateral, with no particular side preference, and may present as unifocal or multifocal, suggesting a possible systemic origin or underlying factors affecting the entire vascular or metabolic system [9]. In our study, simultaneous involvement of both the femoral and humeral epiphyses was rare but in line with literature findings.

The presence of ONFH within the same family might indicate a hereditary or

familial factor [10]. In our study, five cases were observed within one family, although no known genetic disease was identified, suggesting a need for further etiological investigation to explore this potential causal link.

ONFH significantly impacts patients' quality of life, manifesting as hip pain, functional loss, and sometimes severe disability. In some cases, the disease is discovered incidentally during a radiological exam for other reasons. In our series, almost all patients experienced pain, with some facing disability. Delayed consultation and management, often due to socio-economic, geographical, and cultural factors, contributed to worsening and more severe lesions, as reflected in radiological findings.

Currently, early diagnosis is more accurate thanks to the use of magnetic resonance imaging (MRI) [11]. However, the origin of ONFH is often unknown [2] [12]. It is crucial to actively search for associated risk factors, whether linked to individual predispositions or external factors/events. Potential risk factors for ONFH are numerous and well-documented in the literature [2] [13]. Medical history, clinical examination, and laboratory tests can identify these factors in around 70% of cases, which is essential for preventing disease progression.

In Western literature, prolonged corticosteroid use is cited as one of the primary causes of ONFH [14]. Corticosteroids are thought to alter lipid metabolism, causing hyperlipidemia, which leads to fat micro embolisms that obstruct blood vessels, reducing blood flow to the bones and causing necrosis [15]. Animal models support this hypothesis, with studies showing that rabbits receiving weekly methylprednisolone injections for six weeks had a significant reduction in blood flow to the femoral head, reinforcing the idea that corticosteroids disrupt bone vascularization [16]. In our study, five patients had prolonged and repeated corticosteroid use, either through daily boluses or intravenous injections. Additionally, intra-articular injections were associated with one case of osteonecrosis.

Chronic alcohol abuse is also considered a significant risk factor for ONFH. Literature suggests that chronic alcoholism increases urinary excretion of calcium, magnesium, and zinc, which are essential for bone health. Zinc deficiency, in particular, has been identified as a factor promoting osteoporosis, due to its link with hypogonadism. Reduced sex hormone levels and increased cortisol, commonly observed in chronic alcoholics, can indirectly cause osteopenia and contribute to the development of osteonecrosis [17]. Alcohol also has direct toxicity on osteocytes, which are responsible for maintaining bone structure [2].

In the study by Kakpovi K. *et al.*, conducted in Togo [18], alcohol consumption was the second most significant risk factor for ONFH, affecting 28.2% of patients. In contrast, in our series, the proportion of chronic alcoholism was relatively low, at 12.7%. This difference may be explained by cultural, environmental, or methodological variations between the studies. Three patients in our series reported regular consumption of a local alcoholic beverage called Lutuku, which is homebrewed with uncontrolled alcohol content. Such conditions may lead to adverse effects on health, including bone metabolism, due to potential direct toxicity or

alterations in metabolic processes linked to chronic alcoholism [19].

Regarding diabetes, a study in Taiwan region comparing diabetic and non-diabetic cohorts found that the overall incidence of ONFH was 1.37 times higher in the diabetic group compared to the non-diabetic group [20]. This link may be explained by the metabolic effects of diabetes, particularly diabetic microangiopathy, which affects bone vascularization, as well as lipid and inflammatory disorders associated with the disease. These factors reduce blood flow to bones, promoting necrosis. Metabolic disorders such as diabetes, gout, obesity, and liver diseases have all been shown to contribute to the development of ONFH [21]. One patient in our series with ONFH had previously undergone amputation of the contralateral limb, highlighting the systemic nature of diabetes, recognized as a potential cause of ONFH.

In our series, 23.6% of patients had sickle cell disease, which is considered the primary cause of ONFH in sub-Saharan Africa [18] [22]-[27]. Sickle cell disease is a major health issue in the Democratic Republic of the Congo (DRC), where about 25% of the population carries the sickle cell trait, and around 50,000 children are born with the disease each year. This makes the DRC the second most affected country in Africa, after Nigeria [28] [29]. The disease causes red blood cells to become sickle-shaped, leading to vascular obstruction [30]. The resulting ischemia and secondary bone pressure contribute to pain and necrotic lesions in the femoral head [31]. Sickle cell-related osteonecrosis can affect one or multiple joints, with the hip being the most common site.

ONFH in sickle cell disease is frequently cited as the leading indication for hip prostheses in sub-Saharan countries [22] [23] (**Figure 6**, **Figure 7**). This highlights the scale of the public health issue related to sickle cell disease in our region, where osteonecrosis is a major cause of disability. This situation emphasizes the urgent need to raise awareness about early sickle cell disease screening to prevent complications like ONFH and improve patients' quality of life.

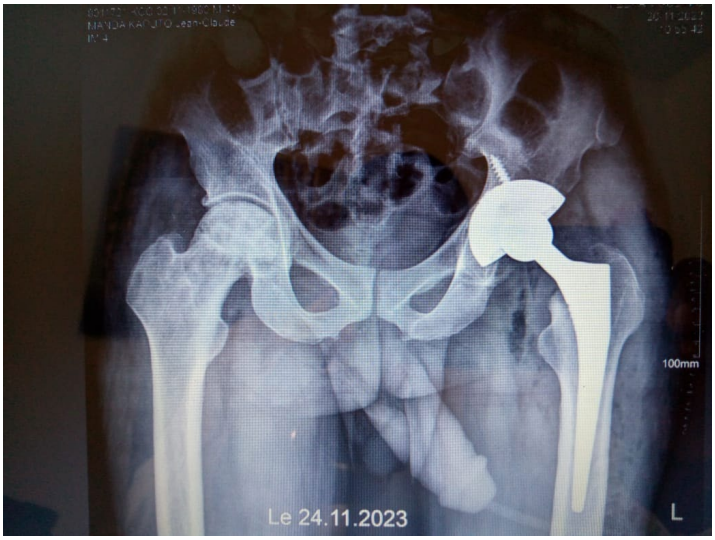

Figure 6. Total left femoral head prosthesis.

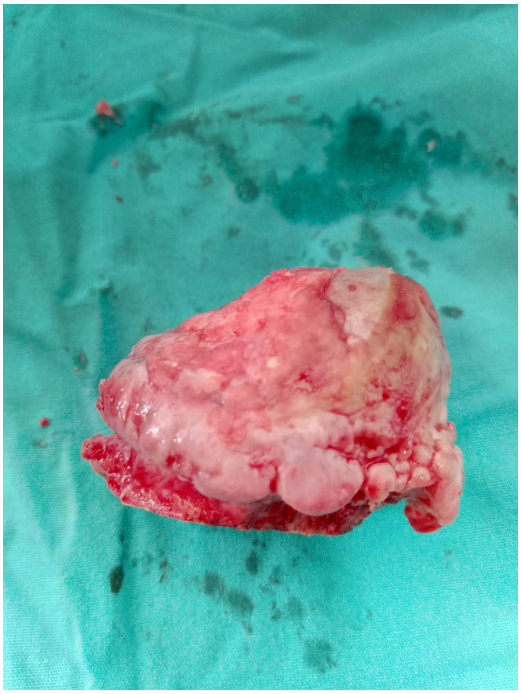

Figure 7. Necrotic femoral head removed during hip arthroplasty.

Other conditions such as leukemia [32], chemotherapy [33], and clotting disorders may increase the risk of ONFH. Autoimmune diseases like systemic lupus erythematosus [34] may also be linked to ONFH due to chronic inflammation and immunosuppressive treatments. Organ transplant recipients, particularly those who have received a kidney transplant, may also develop ONFH due to immunosuppressive medications [35].

Recent research on HIV has shown that the rate of ONFH has risen significantly among infected individuals, being 100 times higher than in the general population [36]. ONFH has been identified as a potential side effect of potent antiretroviral treatments, possibly in association with hyperlipidemia [37].

Interestingly, in our series, 33 (36.6%) patients had no identifiable classical risk factors. Most lived near mining areas, particularly in the cities of Kolwezi, Likasi, and Lubumbashi. Could environmental or professional factors specific to these mining regions contribute to the development of aseptic femoral head osteonecrosis (ONFH)?

Professionally, more than half of these patients worked as miners, where they were exposed to demanding physical tasks such as carrying heavy loads and daily hill surveying. Literature indicates that such physical strains and challenging working conditions may lead to repeated microtrauma, which, while less apparent, could play a crucial role in the development of ONFH. These microtraumas can harm bone vascularization [4], an essential factor in triggering ONFH, making these professional factors significant, even if their contribution is sometimes underestimated.

Environmental factors might also play a role. Some studies suggest that exposure

to high levels of heavy metals in mining regions could disrupt the balance of essential trace elements in the body, contributing to the development of ONFH in individuals with no other known risk factors. This hypothesis was first mentioned by Eschberger *et al.* in 1978 [38]. Since then, limited research has supported this idea, highlighting the toxicity of heavy metals on vascularization and bone metabolism.

Soils contain very small amounts (less than 0.1%) of trace metallic elements (TME). While some of these elements are necessary for life (trace elements), they can become toxic if in excess. Essential metals such as zinc and copper are concentrated in highly mineralized tissues like bones. Zinc supports bone formation and plays a key role in ossification and proper mineralization, especially in the femoral epiphysis. Copper is involved in redox processes, and copper deficiency can lead to thinning of compact bone layers, making them fragile and more prone to fractures.

In contrast to essential metals, toxic metals such as lead (Pb), cadmium (Cd), and mercury (Hg) have harmful effects on bone health. Lead, in particular, accumulates in the bone system, reducing bone mass and delaying mental development and skeletal growth [39]. Studies have shown that lead accumulates in fracture calluses and its concentration significantly increases in the spongy bone of the femoral head in cases of idiopathic or ischemic necrosis [40]. Cadmium can cause vitamin D-resistant osteomalacia, especially in areas contaminated with other metals [41]. Research has also revealed high cadmium concentrations in fracture calluses in laboratory animals and a statistically significant increase in cadmium in the femoral head in cases of idiopathic ischemia. Although mercury has been less studied than other metals, it also poses risks for bone. Lead, in particular, accumulates in the bone system, reducing bone mass and delaying mental development and skeletal growth [39]. Studies have shown that lead accumulates in fracture calluses, and its concentration significantly increases in the spongy bone of the femoral head in cases of idiopathic or ischemic necrosis [40]. Cadmium, on the other hand, can cause vitamin D-resistant osteomalacia, especially in areas contaminated by other metals [41]. Research has also revealed high cadmium concentrations in fracture calluses in laboratory animals and a statistically significant increase of cadmium in the femoral head in cases of idiopathic ischemia. Mercury, though less studied than other metals, also presents risks to bone health. All of these metals can disrupt bone metabolism and are considered true environmental pollutants. Their concentration in bone tissues, due to the slow recovery of bone, may reflect the pollution level of the environment.

A study conducted in 1988 by K.A. Milachowski compared heavy metal concentrations in two patient groups: those with idiopathic femoral head osteonecrosis (ONFH) and those suffering from coxarthrosis. The results revealed statistically and significantly higher levels of toxic metals such as cadmium, nickel, and lead in the femoral head of patients with idiopathic femoral head necrosis. This study was carried out in a contaminated area [42].

Toxic metals remain a major public health issue, particularly in regions with high mining and metallurgical activity [43] [44].

The Katanga province, rich in natural resources, is one of the primary mining hubs in the DRC. However, intensive mining has led to severe environmental and health consequences. Heavy metals such as copper, cobalt, cadmium, and lead are frequently released into the environment through wastewater, mining residues, and air emissions. These toxic substances enter rivers that serve as water sources for local populations, contaminating not only drinking water but also agricultural land and aquatic ecosystems [45] [46]. This pollution can lead to serious health problems, including respiratory and kidney diseases, cancers, and developmental disorders in children. Studies conducted in the former Katanga province have linked these toxic trace metals (ETM) to conditions such as reduced fertility [47] and neurodevelopmental disorders in children [48]. However, no specific studies have yet been conducted on the effects of toxic metals on the musculoskeletal system in this region. While scientific literature has explored this avenue, the exact mechanisms through which heavy metals could impair bone vascularization or induce necrotic processes remain unclear. Toxic elements could potentially trigger oxidative stress, leading to vascular damage, inflammation, or metabolic dysfunctions, thus increasing the risk of developing ONFH [49]. Further research is essential to better understand these potential interactions and identify at-risk populations, in order to implement effective preventive strategies.

6. Conclusion

Beyond the well-established risk factors for femoral head osteonecrosis, particularly sickle cell disease, our study highlights a considerable number of ONFH cases with no identifiable risk factor, classified as idiopathic. This group is primarily composed of young individuals, some of whom work in mining areas. This observation raises an important question regarding a possible association between exposure to heavy metals, commonly found in these mining environments, and the development of femoral head osteonecrosis. Although this hypothesis has rarely been explored in the literature, studies on the impact of heavy metals such as lead and cadmium on bone health are limited, leaving this question largely unexplained and open to future research.

Conflicts of Interest

The authors declare no conflict of interest.

References

[1] Petek, D., Hannouche, D. and Suva, D. (2019) Osteonecrosis of the Femoral Head: Pathophysiology and Current Concepts of Treatment. *EFORT Open Reviews*, **4**, 85-97. https://doi.org/10.1302/2058-5241.4.180036

[2] Pijnenburg, L., Felten, R. and Javier, R.-M. (2020) Ostéonécroses aseptiques, une revue générale des ostéonécroses de la hanche, et au-delà. *La Revue de Médecine Interne*, **41**, 27-36. https://doi.org/10.1016/j.revmed.2019.10.332

[3] Wells, M.E. and Dunn, J.C. (2022) Pathophysiology of Avascular Necrosis. *Hand Clinics*, **38**, 367-376. https://doi.org/10.1016/j.hcl.2022.03.011

[4] Lafforgue, P. (2006) Physiopathologie et évolution naturelle des ostéonécroses. *Revue du Rhumatisme*, **73**, 887-894. https://doi.org/10.1016/j.rhum.2006.01.020

[5] Ficat, R. (1985) Idiopathic Bone Necrosis of the Femoral Head. Early Diagnosis and Treatment. *The Journal of Bone and Joint Surgery*, **67**, 3-9. https://doi.org/10.1302/0301-620x.67b1.3155745

[6] Moya-Angeler, J. (2015) Current Concepts on Osteonecrosis of the Femoral Head. *World Journal of Orthopedics*, **6**, 590-601. https://doi.org/10.5312/wjo.v6.i8.590

[7] Cooper, C., Steinbuch, M., Stevenson, R., Miday, R. and Watts, N.B. (2009) The Epidemiology of Osteonecrosis: Findings from the GPRD and THIN Databases in the UK. *Osteoporosis International*, **21**, 569-577. https://doi.org/10.1007/s00198-009-1003-1

[8] Manga, A., Yamben, M.A.N., Kolontchang, L., Ashu, M., Mokom, P. and Ibrahima, F. (2018) Surgical Treatment of Coxarthrosis by Total Hip Arthroplasty at the National Rehabilitation Centre for Disabled Persons in Yaoundé. *Health Sciences and Disease*, **19**.

[9] Guerado, E. and Caso, E. (2016) The Physiopathology of Avascular Necrosis of the Femoral Head: An Update. *Injury*, **47**, S16-S26. https://doi.org/10.1016/s0020-1383(16)30835-x

[10] Sekkat, J., Rachidi, O., Janani, S. and Mkinsi, O. (2012) Ostéonécrose aseptique idiopathique des têtes fémorales chez cinq membres d'une famille marocaine. *Revue du Rhumatisme*, **79**, 466-468. https://doi.org/10.1016/j.rhum.2012.04.013

[11] Hoang, M.L., Perdriel, B., Provost, N. and Fournier, L. (2005) OA73 Osteonecrose aseptique de la tete femorale: Correlation anatomo-pathologique et imagerie par resonance magnetique (IRM). *Journal de Radiologie*, **86**, 1539. https://doi.org/10.1016/s0221-0363(05)76214-4

[12] Mont, M.A., Salem, H.S., Piuzzi, N.S., Goodman, S.B. and Jones, L.C. (2020) Nontraumatic Osteonecrosis of the Femoral Head: Where Do We Stand Today? *Journal of Bone and Joint Surgery*, **102**, 1084-1099. https://doi.org/10.2106/jbjs.19.01271

[13] Guggenbuhl, P., Robin, F., Cadiou, S. and Albert, J.D. (2021) Etiology of Avascular Osteonecrosis of the Femoral Head. *Morphologie*, **105**, 80-84. https://doi.org/10.1016/j.morpho.2020.12.002

[14] Liu, L., Zhang, Q., Sun, W., Li, Z. and Gao, F. (2017) Corticosteroid-Induced Osteonecrosis of the Femoral Head. *Chinese Medical Journal*, **130**, 2601-2607. https://doi.org/10.4103/0366-6999.217094

[15] Weldon, D. (2009) The Effects of Corticosteroids on Bone: Osteonecrosis (Avascular Necrosis of the Bone). *Annals of Allergy, Asthma & Immunology*, **103**, 91-98. https://doi.org/10.1016/s1081-1206(10)60159-7

[16] Wu, X., Yang, S., Duan, D., Zhang, Y. and Wang, J. (2008) Experimental Osteonecrosis Induced by a Combination of Low-Dose Lipopolysaccharide and High-Dose Methylprednisolone in Rabbits. *Joint Bone Spine*, **75**, 573-578. https://doi.org/10.1016/j.jbspin.2007.11.004

[17] Laitinen, K. and Välimäki, M. (1991) Alcohol and Bone. *Calcified Tissue International*, **49**, S70-S73. https://doi.org/10.1007/bf02555094

[18] Kakpovi, K., Fianyo, E., Zabsonré/Tiendrébéogo, W., Zidol, K., Houzou, P., Tagbor, K., *et al.* (2022) Ostéonécrose aseptique de la tête fémorale en milieu rhumatologique au Togo. *Rhumatologie Africaine Francophone*, **2**, 1-6. https://doi.org/10.62455/raf.v2i1.10

[19] Jacobs, B. (1992) Alcoholism-Induced Bone Necrosis. *New York State Journal of Medicine*, **92**, 334-338.

[20] Lai, S., Lin, C. and Liao, K. (2018) Real-World Database Examining the Association between Avascular Necrosis of the Femoral Head and Diabetes in Taiwan Region. *Diabetes Care*, **42**, 39-43. https://doi.org/10.2337/dc18-1258

[21] Lai, S., Lin, C. and Liao, K. (2017) Use of Oral Corticosteroids and Risk of Hip Fracture in the Elderly in a Case-Control Study. *Frontiers in Pharmacology*, **8**, Article 625. https://doi.org/10.3389/fphar.2017.00625

[22] Trop, M. (2009) Total Hip Arthroplasty in Sickle Cell Disease-Related Aseptic Osteonecrosis in Senegal: Series of 48 Prostheses. *Médecine Tropicale*, **69**, 573-576.

[23] Massadiami, S., Malick, D., Rokiatou, K., Ida, T.A., Souleymane, O., Adama, S. and Patrick, W.H.D. (2021) Total Hip Arthroplasty in a Resource-Limited Country: Evaluation of Mid-Term Results. *Mali Médical*, **36**, 23-27.

[24] Homawoo, K., Bissang, K., Songne, B. and Ayite, A. (1991) Sickle Cell Disease and Osteonecrosis of the Femoral Head. *Médecine d'Afrique Noire*, **38**.

[25] Ibrahima, F., Fokam, P., Ngongang, F.-O. and Esiéné, A. (2014) Résultats préliminaires des prothèses totales de hanche réalisées dans un pays africain à ressources limitées. *Revue de Chirurgie Orthopédique et Traumatologique*, **100**, 264-268. https://doi.org/10.1016/j.rcot.2014.02.017

[26] Lanocha, N., Kalisinska, E., Kosik-Bogacka, D.I., Budis, H., Sokolowski, S. and Bohatyrewicz, A. (2012) Concentrations of Trace Elements in Bones of the Hip Joint from Patients after Hip Replacement Surgery. *Journal of Trace Elements in Medicine and Biology*, **26**, 20-25. https://doi.org/10.1016/j.jtemb.2011.11.006

[27] Kouakou, E., Sougué, C., Yao, K., Traore, A., Koff, J., Goua, J.J. and Daboiko, J.C.F. (2023) Aseptic Osteonecrosis Seen in Rheumatology in Abidjan between 2001 and 2011: Epidemiological and Diagnostic Characteristics of 31 Patients. *ESI Preprints*, **16**, 235-235.

[28] Agasa, B., Bosunga, K., Opara, A., Tshilumba, K., Dupont, E., Vertongen, F., *et al.* (2010) Prevalence of Sickle Cell Disease in a Northeastern Region of the Democratic Republic of Congo: What Impact on Transfusion Policy? *Transfusion Medicine*, **20**, 62-65. https://doi.org/10.1111/j.1365-3148.2009.00943.x

[29] Tshilolo, L., Aissi, L.M., Lukusa, D., Kinsiama, C., Wembonyama, S., Gulbis, B., *et al.* (2008) Neonatal Screening for Sickle Cell Anaemia in the Democratic Republic of the Congo: Experience from a Pioneer Project on 31 204 Newborns. *Journal of Clinical Pathology*, **62**, 35-38. https://doi.org/10.1136/jcp.2008.058958

[30] Galacteros, F. (2004) Pathophysiology of Sickle Cell Disease, from Theory to Practical Aspects: Sickle Cell Disease. *La Revue du Praticien* (*Paris*), **54**, 1534-1542.

[31] Mukisi, M.M., Bashoun, K. and Burny, F. (2009) Sickle-Cell Hip Necrosis and Intraosseous Pressure. *Orthopaedics & Traumatology*: *Surgery & Research*, **95**, 134-138. https://doi.org/10.1016/j.otsr.2009.01.001

[32] Béguin, A., Bertrand, Y., Ourcival, S., Foray, P., Manel, A.M. and Philippe, N. (1999) Ostéonécrose aseptique de la tête fémorale au cours du traitement des leucémies aiguës lymphoblastiques de l'enfant. *Archives de Pédiatrie*, **6**, 971-974. https://doi.org/10.1016/s0929-693x(99)80591-0

[33] Magné, N., Foa, C., Bruneton, J.N. and Marcy, P.Y. (2001) Séminome du testicule et ostéonécrose aseptique multifocale au décours d'une chimiothérapie. *La Revue de Médecine Interne*, **22**, 62-64. https://doi.org/10.1016/s0248-8663(00)00286-1

[34] Tse, S.M. and Mok, C.C. (2016) Time Trend and Risk Factors of Avascular Bone Necrosis in Patients with Systemic Lupus Erythematosus. *Lupus*, **26**, 715-722. https://doi.org/10.1177/0961203316676384

[35] Felten, R., Perrin, P., Caillard, S., Moulin, B. and Javier, R. (2019) Avascular

Osteonecrosis in Kidney Transplant Recipients: Risk Factors in a Recent Cohort Study and Evaluation of the Role of Secondary Hyperparathyroidism. *PLOS ONE*, **14**, e0212931. https://doi.org/10.1371/journal.pone.0212931

[36] Gallant, J.E. (2012) Johns Hopkins HIV Guide 2012. Jones & Bartlett Publishers.

[37] Mary-Krause, M., Billaud, E., Poizot-Martin, I., Simon, A., Dhiver, C., Dupont, C., *et al.* (2006) Risk Factors for Osteonecrosis in Hiv-Infected Patients: Impact of Treatment with Combination Antiretroviral Therapy. *AIDS*, **20**, 1627-1635. https://doi.org/10.1097/01.aids.0000238409.90571.02

[38] Eschberger, J., Maruna, R.F.L. and Trojan, E. (1978) Morphological and Biochemical Studies on Femoral Heads after Femoral Neck Fractures. *Acta Medica Austriaca*, **11**, Article No. 5.

[39] Berlin, K., Gerhardsson, L., Börjesson, J., Lindh, E., Lundström, N., Schütz, A., *et al.* (1995) Lead Intoxication Caused by Skeletal Disease. *Scandinavian Journal of Work, Environment & Health*, **21**, 296-300. https://doi.org/10.5271/sjweh.42

[40] Quint, P., Althoff, J., Reiling, H.E. and Höhling, H.J. (1982) Inversvoltammetrische Bestimmung von Cd, Cu, Pb und Zn für verschiedene Stadien der Knorpelmineralisation. *Fresenius' Zeitschrift für analytische Chemie*, **311**, 415-416. https://doi.org/10.1007/bf00481781

[41] Horiguchi, H., Oguma, E., Sasaki, S., Miyamoto, K., Hosoi, Y., Ono, A., *et al.* (2020) Exposure Assessment of Cadmium in Female Farmers in Cadmium-Polluted Areas in Northern Japan. *Toxics*, **8**, Article 44. https://doi.org/10.3390/toxics8020044

[42] Milachowski, K.A. (1988) Investigation of Ischaemic Necrosis of the Femoral Head with Trace Elements. *International Orthopaedics*, **12**, 323-330. https://doi.org/10.1007/bf00317832

[43] Brodziak-Dopierała, B., Kowol, J., Kwapuliński, J., Kusz, D. and Cieliński, Ł. (2011) Lead and Calcium Content in the Human Hip Joint. *Biological Trace Element Research*, **144**, 6-16. https://doi.org/10.1007/s12011-011-9014-0

[44] García, F., Ortega, A., Domingo, J.L. and Corbella, J. (2001) Accumulation of Metals in Autopsy Tissues of Subjects Living in Tarragona County, Spain. *Journal of Environmental Science and Health, Part A*, **36**, 1767-1786. https://doi.org/10.1081/ese-100106258

[45] Banza, C.L.N., Nawrot, T.S., Haufroid, V., Decrée, S., De Putter, T., Smolders, E., *et al.* (2009) High Human Exposure to Cobalt and Other Metals in Katanga, a Mining Area of the Democratic Republic of Congo. *Environmental Research*, **109**, 745-752. https://doi.org/10.1016/j.envres.2009.04.012

[46] Katemo Manda, B., Colinet, G., Andre, L., Chocha Manda, A., Marquet, J.P. and Micha, J.C. (2010) Evaluation of Contamination in the Food Chain by Trace Elements (Cu, Co, Zn, Pb, Cd, U, V, and As) in the Upper Lufira Basin (Katanga/DRC). *Tropicultura*, **28**, 246-252.

[47] Mukendi, R., Banza, C.L.N., Mukeng, C., Ngwe, J.T.M., Mwembo, A.N. and Kalenga, P.M.K. (2018) Exposition de l'homme aux éléments tracés métalliques et altération du sperme: étude menée dans les zones minières du Haut-Katanga en République Démocratique du Congo. *Pan African Medical Journal*, **30**, Article 35. https://doi.org/10.11604/pamj.2018.30.35.13694

[48] Koba, B.B. (2018) Electroencephalographic Slowing in School-Age Children Exposed to Trace Metals in Lubumbashi, DR Congo. *Africain Journal of Medicine and Public Health*, 2, Article No. 1.

[49] Haleng, J., Pincemail, J., Defraigne, J.O., Charlier, C. and Chapelle, J.P. (2007) Oxidative Stress. *Revue Médicale de Liège*, **62**, 628-638.