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ORIGINAL ARTICLE

Chronic alcohol abuse in men alters bone mechanical properties by affecting both tissue mechanical properties and microarchitectural parameters

L'abus d'alcool chronique chez les hommes modifie les propriétés mécaniques de l'os en affectant à la fois la qualité du tissu et les paramètres micro-architecturaux

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KEYWORDS
Osteoporosis;
Alcohol abuse;
Mechanical properties;
Bone microarchitectural parameters

Summary
Objective of the study. — Alcohol-induced secondary osteoporosis in men has been characterized by higher fracture prevalence and a modification of bone microarchitecture. Chronic alcohol consumption impairs bone cell activity and results in an increased fragility. A few studies highlighted effects of heavy alcohol consumption on some microarchitectural parameters of trabecular bone. But to date and to our knowledge, micro- and macro-mechanical properties of bone of alcoholic subjects have not been investigated.
Patients. — In the present study, mechanical properties and microarchitecture of trabecular bone samples from the iliac crest of alcoholic male patients ($n = 15$) were analyzed and compared to a control group ($n = 8$).
Materials and methods. — Nanoindentation tests were performed to determine the tissue's micromechanical properties, micro-computed tomography was used to measure microarchitectural parameters, and numerical simulations provided the apparent mechanical properties of the samples.

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Results. — Compared to controls, bone tissue from alcoholic patients exhibited an increase of micromechanical properties at tissue scale, a significant decrease of apparent mechanical properties at sample scale, and significant changes in several microarchitectural parameters. In particular, a crucial role of structure model index (SMI) on mechanical properties was identified.
Conclusions. — 3D microarchitectural parameters are at least as important as bone volume fraction to predict bone fracture risk in the case of alcoholic patients.

MOTS CLÉS
Ostéoporose ;
Abus d'alcool ;
Propriétés mécaniques ;
Paramètres micro-architecturaux osseux

Résumé
Objectif de l'étude. — L'ostéoporose secondaire induite par l'alcool chez les hommes a été caractérisée par une prévalence plus élevée de fracture et une modification de la micro-architecture osseuse. La consommation chronique d'alcool altère l'activité des cellules et augmente la fragilité osseuse. Quelques études ont mis en évidence les effets de la consommation excessive d'alcool sur certains paramètres micro-architecturaux de l'os trabéculaire. Mais à ce jour et à notre connaissance, les propriétés micro- et macro-mécanique de l'os provenant de sujets alcooliques n'ont pas été étudiées.
Patients. — Dans la présente étude, les propriétés mécaniques et la micro-architecture d'échantillons d'os trabéculaire provenant de la crête iliaque de patients de sexe masculin alcooliques ($n = 15$) ont été analysés et comparés à un groupe témoin ($n = 8$).
Matériels et méthodes. — Des tests de nanoindentation ont été réalisés pour déterminer les propriétés micromécaniques du tissu. La micro-tomodensitométrie a été utilisée pour mesurer les paramètres de micro-architecture et des simulations numériques éléments finis ont fourni les propriétés mécaniques apparentes des échantillons.
Résultats. — Par rapport aux témoins, le tissu osseux chez les patients alcooliques présentaient une augmentation des propriétés micromécaniques à l'échelle tissulaire, une diminution significative des propriétés mécaniques apparentes à l'échelle de l'échantillon et des changements importants dans plusieurs paramètres micro-architecturaux. En particulier, un rôle crucial du Structure Model Index sur les propriétés mécaniques a été identifié.
Conclusions. — Les paramètres micro-architecturaux 3D sont au moins aussi importants que la fraction volumique osseuse pour prédire le risque de fracture osseuse dans le cas des patients alcooliques.

Introduction

Osteoporosis is now defined as a diffuse skeletal disease characterized by a combination of low bone mass and microarchitectural alterations of bone tissue leading to enhanced bone fragility and an increased risk of fracture [1]. Osteoporosis has long been considered as a female disease only but, over the past few years, the increase of life expectancy led to recognize osteoporosis in men as a public health issue as well [2]. Hip fractures due to osteoporosis are two to three times less common in men than in women, but the associated morbidity and mortality are at least twice higher in men than in women [3]. The majority of cases of male osteoporosis are secondary osteoporosis either caused by glucocorticoid therapy, alcohol abuse, hypogonadism (low levels of testosterone), hepatic and digestive diseases, smoking, hypercalciuria, or immobilization [4]. The present study focused on one primary cause: alcohol abuse.

Alcohol abuse was found to result in an unbalanced bone remodeling with fewer osteoblasts and reduced bone formation [5]. In vitro studies showed that ethanol affects mesenchymal stem cells by prolonging doubling time [6] and orienting them towards a differentiation into adipocytes to the detriment of osteoblasts [7,8]. Osteoblasts are also directly affected, not through an increased apoptosis but through a decreased proliferation and an impaired function: protein synthesis and alkaline phosphatase activity are reduced by alcohol in a dose-dependent manner [9—13]. This mechanism may be secondary to the decrease in testosterone levels [14]. Alcohol increases osteocyte apoptosis and leads to abnormal changes in cell morphology [7]. The literature on alcohol effects on osteoclasts is more controversial. Some studies showed that alcohol had a direct effect on osteoclasts in vitro resulting in increased bone resorption [12,15] but others found no significant modifications [9,16]. The increase in eroded surfaces observed on histomorphometric studies may be the reflection of the decreased osteoblastic activity [14].

Alcohol effects on bone mineral density (BMD) have been evidenced by Dual Energy X-Ray absorptiometry. In young men, a low to moderate alcohol consumption results in an increased BMD while heavy alcohol consumption is detrimental to BMD [17,18]. There is evidence that BMD is negatively correlated with the duration of alcohol abuse [19]. However, BMD is only one parameter influencing bone resistance and may not be sufficient to characterize alcohol-induced osteoporosis. Indeed, there is a plethora of evidence that factors other than BMD, encompassed under the term ''bone quality'', influence bone's ability to resist fracture [20,21].