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# EFFECTS OF COMBAT SPORTS ON BONE MASS: SYSTEMATIC REVIEW



REVIEW ARTICLE  
ARTIGO DE REVISÃO  
ARTÍCULO DE REVISIÓN

EFEITO DOS ESPORTES DE COMBATE SOBRE A MASSA ÓSSEA: REVISÃO SISTEMÁTICA

EFFECTO DE LOS DEPORTES DE COMBATE SOBRE LA MASA ÓSEA: REVISIÓN SISTEMÁTICA

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## ABSTRACT

**Objective:** To determine the influence of combat sports on bone mass. **Methods:** A systematic review was performed according to the PRISMA method, with searches in the Pubmed, Bireme, Embase and Web of Science databases covering the period 1900 to 2015, using the keywords “martial arts”, “fight”, “combat”, “karate”, “kung fu”, “tae kwon do”, “judo”, “aikido”, “bone mass”, “bone health”, “bone tissue”, “bone density”, and “bone mineral contents”. The articles were searched for and retrieved electronically and manually, by two independent reviewers. **Results:** Seventy-nine articles were identified, of which 25 were duplicates, leaving 54 for reading and evaluation of the titles; next, articles about diseases such as bone and/or orthopedic injuries, maxillofacial, surgeries, fractures, osteoporosis and osteopenia in women, prevention of falls, and physical fitness were excluded, leaving 15 articles. Of the articles selected and retrieved in full, all were published between 2002 and 2015. One article was a case control study; two were longitudinal studies, two were randomized studies; and 10 were cross-sectional studies. A total of 1368 children, adolescents, adults and elderly subjects were involved in combat sports and had bone evaluation by imaging. Factors such as calorie intake, calcium and/or vitamin D, intensity and volume of the exercise, hormonal aspects as bone markers, and characteristics of menopause are not conclusive in relation to bone mass, and further studies are needed. **Conclusion:** The practice of combat sports shows a significant improvement in bone mass at all ages. **Level of Evidence III, Therapeutic study – Investigation of treatment results.**

**Keywords:** Sports performance; Sports; Bone tissue; Bone mineral density.

## RESUMO

**Objetivo:** Verificar a influência dos esportes de combate sobre a massa óssea. **Métodos:** Foi realizada revisão sistemática da literatura de acordo com o método PRISMA, com buscas nas bases de dados Pubmed, Bireme, Embase e Web of Science, referente ao período de 1900 a 2015, com os descritores “martial arts”, “fight”, “combat”, “karate”, “kung fu”, “tae kwon do”, “judo”, “aikido”, “bone”, “bone mass”, “bone health”, “bone tissue”, “bone density”, “bone mineral contents”. A busca e a recuperação dos artigos foram realizadas por meio eletrônico e manual, executadas por dois revisores independentes. **Resultados:** Foram identificados 79 artigos, dos quais, 25 eram duplicados, restando 54 artigos para leitura e avaliação dos títulos; posteriormente, foram excluídos os que tratavam de doenças como lesões ortopédicas e/ou ósseas, maxilofaciais, cirurgias, fraturas, mulheres osteopênicas e osteoporóticas, prevenção de quedas e aptidão física, restando 15 artigos. Dos estudos selecionados e encontrados na íntegra, todos foram publicados entre 2002 e 2015. Apenas um era estudo de caso controle, dois eram estudos longitudinais, dois estudos randomizados e 10 estudos transversais. Verificou-se um total de 1.368 crianças, adolescentes, adultos e idosos envolvidos em esportes de combate e avaliação óssea por imagem. Fatores como ingestão calórica, de cálcio e/ou vitamina D, intensidade e volume do exercício, aspectos hormonais como marcadores ósseos e características da menopausa não são conclusivos com relação à massa óssea e requerem um número maior de estudos. **Conclusão:** A prática de esportes de combate evidencia melhora significativa na massa óssea em todas as idades. **Nível de Evidência III, Estudos terapêuticos – Investigação dos resultados do tratamento.**

**Descritores:** Desempenho esportivo; Atividades esportivas; Tecido ósseo; Densidade mineral óssea.

## RESUMEN

**Objective:** To determine the influence of combat sports on bone mass. **Methods:** A systematic review was performed according to the PRISMA method, with searches in the Pubmed, Bireme, Embase and Web of Science databases covering the period 1900 to 2015, using the keywords “martial arts”, “fight”, “combat”, “karate”, “kung fu”, “tae kwon do”, “judo”, “aikido”, “bone mass”, “bone health”, “bone tissue”, “bone density”, and “bone mineral contents”. The articles were searched for and retrieved electronically and manually, by two independent reviewers. **Results:** Seventy-nine articles were identified, of which 25 were duplicates, leaving 54 for reading and evaluation of the titles; next, articles about diseases such as bone and/or orthopedic injuries, maxillofacial, surgeries, fractures, osteoporosis and osteopenia in women, prevention of falls, and physical fitness were excluded, leaving 15 articles. Of the articles selected and retrieved in full, all were published between 2002 and 2015. One article was a case control study; two were longitudinal studies, two were randomized studies;



and 10 were cross-sectional studies. A total of 1368 children, adolescents, adults and elderly subjects were involved in combat sports and had bone evaluation by imaging. Factors such as calorie intake, calcium and/or vitamin D, intensity and volume of the exercise, hormonal aspects as bone markers, and characteristics of menopause are not conclusive in relation to bone mass, and further studies are needed. Conclusion: The practice of combat sports shows a significant improvement in bone mass at all ages. **Level of Evidence III, Therapeutic study – Investigation of treatment results.**

**Descriptors:** Rendimiento deportivo; Actividades deportivas; Tejido óseo; Densidad mineral ósea.

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## INTRODUCTION

Adolescence is a crucial period for bone acquisition, as at this stage there is gradual bone growth, reaching 90% of the peak.<sup>1</sup> It is the primary period for bone response to physical exercise.<sup>2,3</sup> Besides, genetic predisposition, physiological factors, calcium intake and vitamin D, active lifestyle and participation in sports are among the most important factors for the acquisition of an adequate bone structure during the period of growth.<sup>2</sup> This acquisition of bone mass in childhood and adolescence is vital to avoid osteopenia and future diseases such as osteoporosis and fractures in adult life.<sup>2</sup>

Therefore, medium and high impact sports, such as fighting (judo, karate, kung fu, taekwondo, boxing, etc.) cause micro fractures in the bone tissue, which stimulate osteogenesis and enhance mechanical stress, promoting beneficial effects on the bone mass.<sup>3-9</sup>

Multiple imaging techniques (radiological or others) are used to evaluate bone mass at pediatric age.<sup>10</sup> The most used ones are DXA (dual-energy X-ray absorptiometry), peripheral quantitative computed tomography (pQCT) and quantitative ultrasound (QUS).<sup>2</sup> The latter does not use ionizing radiation.<sup>11</sup>

Although the benefits of impact sports to bone health are known, little is known about the benefits gained through combat sports.

The objective of this study was to analyze the influence of combat sports on bone mass in children, adolescents, adults and the elderly using different imaging techniques of bone evaluation.

## METHODS

### Search strategy

An extensive electronic research was conducted to identify articles on studies that used bone mass evaluation methods in combat sports in healthy children, adolescents, adults, and the elderly.

This is a systematic review using the PRISMA method (Preferred Reporting Items for Systematic Reviews and Meta-Analyses).<sup>12</sup> The research was carried out using keywords with terms selected and consulted through the Health Sciences Descriptors (DeCS) and Medical Subject Headings (MeSH). The search strategies were developed with a health librarian.

The search was performed from April to May 2015 in four databases: Bireme, Embase, Pubmed and Web of Science. The terms were limited to the English language only: "martial arts", "fight", "combat", "karate", "kung fu", "taekwondo", "judo", "aikido", "bone", "bone health", "bone tissue", "bone density", "bone mineral contents", any suffixes, using the Boolean operators 'AND' and/or 'OR'. Also, the search and retrieval of the articles were performed both electronically and manually by two independent reviewers.

There were no limitations of statistical methods and/or quality of data for the inclusion of articles. The inclusion criteria were: 1) original articles: cross-sectional, longitudinal, randomized and non-randomized; 2) articles on combat sports; 3) bone mass evaluation imaging techniques; 4) studies with human beings: children, adolescents, adults and the elderly; 5) healthy individuals. Exclusion criteria were: 1) injuries caused by combat sports; 2) articles not in English or Portuguese.

The researchers independently initiated the search and evaluation of the studies potentially relevant to this review using a protocol developed for the research, in order to classify the articles according to the study design and strictly complying with the inclusion and exclusion criteria in order to create a selection of articles. As a strategy, this systematic review was conducted with the following steps, to identify and select the articles in the different databases:

First stage: to identify the articles, all titles of the potential studies to be included were read. Those that did not meet any of the inclusion criteria of this study were excluded. Second stage: the abstracts of the studies selected in the first stage were read. Again, those that did not meet any of the inclusion criteria predetermined in this study were rejected. Third stage: all studies selected in the first two stages were fully read (detailed analysis), then the articles used in this review were compiled. Fourth stage: the references of the selected articles were checked. Last stage: after the research and individual evaluation of the researchers, a consensus meeting was held to select the final articles, with a new detailed analysis, following the four stages previously mentioned to resolve doubts and disagreements of the data collected from the reviewers.

## RESULTS

Through the electronic search, 79 articles with the terms in the selected databases were identified. Of these, 25 were excluded because they were repeated. Fifty-four were left to be read and have their titles evaluated. Of these, 39 articles about orthopedic and/or bone injuries, maxillofacial diseases, surgeries, fractures, osteopenic and osteoporotic women, prevention of falls and physical fitness were excluded. Once all the titles were read, there were 16 left to have their abstracts read.

In the references of the selected articles, no relevant article was found. Therefore, 16 articles were left to be read, in which only 15 were found by the researchers of the study. The article by Matsumoto et al.<sup>13</sup> was requested to the librarian, but it was not found, as the journal only makes available the articles published from the year 2000, so it was excluded from the study. (Figure 1)

### Characteristics of the studies

Of the full studies selected and found, all of them were published between 2002 and 2015. One of these articles was a case control study, two were longitudinal studies, two randomized studies and 10 cross-sectional studies. Once all of the 15 selected articles were read, there were 1,368 children, adolescents, adults and elderly people involved in combat sports and bone imaging evaluation.

The equipment for evaluation of the bone evaluation imaging techniques was QUS of phalanges, DXA and pQCT. T and Z scores of the variable Amplitude Dependent Speed of Sound (AD-SoS) were analyzed by QUS of phalanges; and bone mineral density of the spine, lumbar, femur, hip, arm, leg, trunk and total spine by DXA, and distal tibia by pQCT.

The variables analyzed were: age, sex, weight, height, body mass index (BMI), bone tissue, bone mineral density, fat mass, lean mass, appendicular

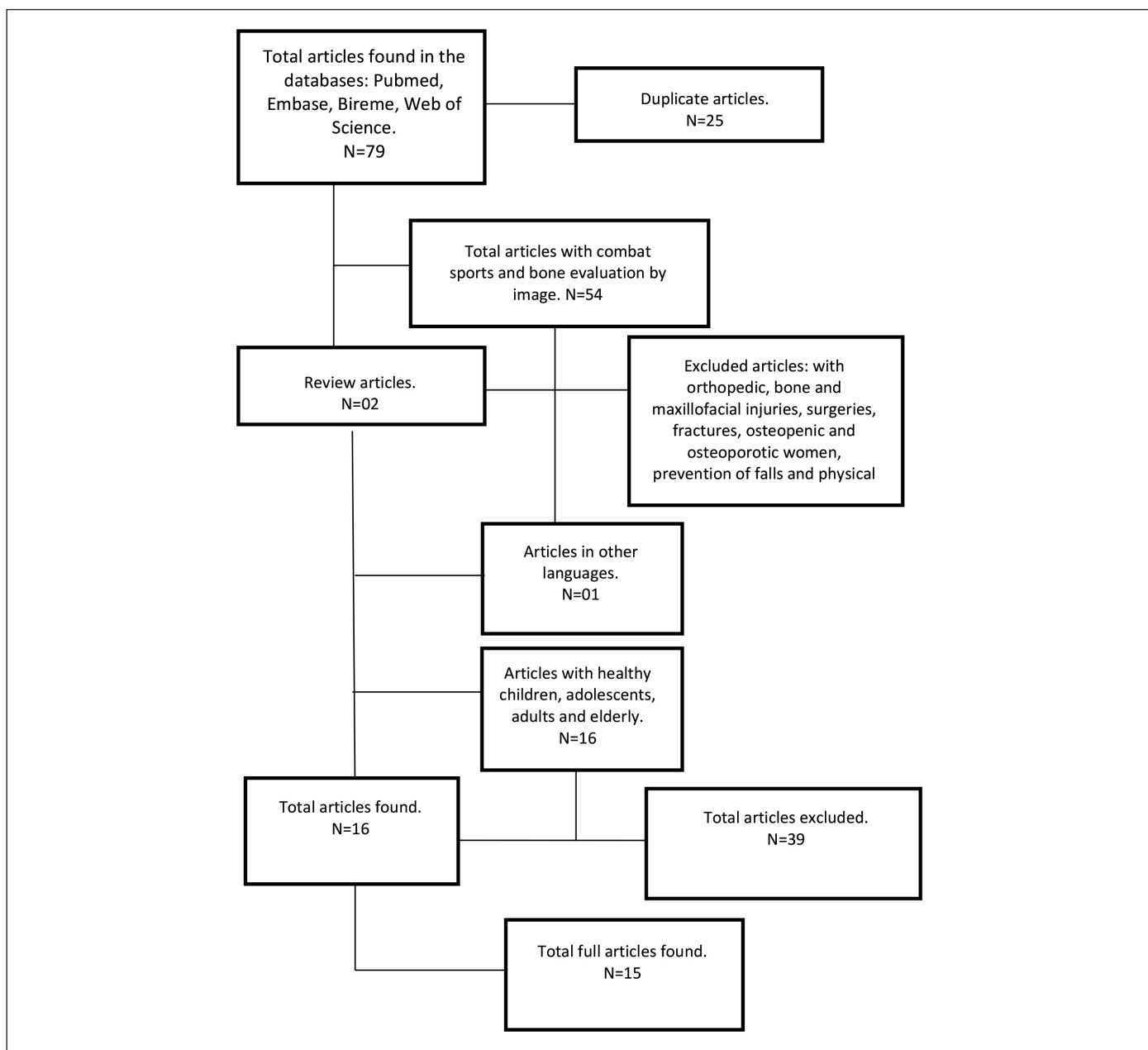


Figure 1. PRISMA flowchart.

muscle mass, smoking and alcohol. Regarding dietary intake: carbohydrates, proteins, fats, calcium, and vitamin D. Regarding exercise: duration, intensity and volume of the exercise, training frequency per week, years of sports practice, dominant and non-dominant hand strength, flexibility, muscle strength, blast force of lower limbs. Regarding hormonal aspects: age of menopause, reproductive years and years since menopause, testosterone, growth hormone, cortisol, bone markers, total protein values.

The summaries of the articles are presented in Table 1. These articles presented an association between DXA (n=11), pQCT (n=2) and QUS of phalanges (n=2), with variables of calcium and/or vitamin D intake (n=4), caloric intake (n=1), exercise: time of physical exercise, intensity and volume (n=7), smoking and alcohol (n=1), hormone 1: menopause, reproductive age and age of menopause (n=4) and hormone 2: cortisol, testosterone and bone markers (n=3).

The combat sports studied and other sports were: Karate, Judo, Kyokushinkai Karate, Tai Chi, Kung Fu, Tai Chi Chun, Taekwondo, Wrestling, Boxing. Walking, resistance exercise, water polo and dancing were also evaluated.

## DISCUSSION

In this study, it was found that the effects of combat sports on bone mass at different ages with healthy individuals were positive. Besides, the results presented other important variables related to bone mass, including: caloric, calcium and vitamin D intake; time, intensity and volume of physical exercise; smoking and alcohol and hormones.

### Calorie, calcium and/or vitamin D intake

Regarding the study by Andreoli et al.,<sup>4</sup> which evaluated caloric intake in adults (athletes and control group) using a food frequency questionnaire,<sup>14</sup> did not present any significant difference between groups for BMI and caloric intake. Judo and karate practitioners had a higher protein intake than water polo and control group. Water polo practitioners had a higher lipid and carbohydrate consumption than judo, karate and control group individuals. There were no differences between the groups of athletes with calcium intake, and the caloric intake was significantly higher in the athletes' group than in the control group. Four other studies evaluated calcium intake, but

**Table 1.** Sample size and main characteristics of the articles.

Study	Sample	Type (Study)	Technique	Place of evaluation	Combat sports	Results and conclusion
Andreoli et al, 2001 <sup>4</sup>	62 Italians (♂) – 18 to 25 years of age	Cross-sectional	DXA	Arms, legs and trunk	Karate, Judo and Water polo	High-impact activities can be a major factor in gaining bone mass and reducing the risk of osteoporosis.
Bozkurt, 2010 <sup>20</sup>	42 Turks (♂) - 18-15 years old	Cross-sectional	DXA	Spine and lumbar	Taekwondo, Wrestling, Judo and Racing	Physical exercises positively affect BMD when they are done regularly and correctly.
Bozkurt, 2010 <sup>20</sup>	42 Turks (♂) - 18-15 years old	Cross-sectional	DXA	Femur	Taekwondo, Wrestling, Judo and Racing	Higher BMD values in the femur region are found in fighters. These activities have a significant effect on bone mineral density
Drozdowska et al, 2011 <sup>5</sup>	226 Polish (♂) – 7 to 61 years	Cross-sectional	QUS AD-SoS Z score T score	Phalanges	Karate	Karate is a sport with a positive influence on bone tissue with more significant benefits in adults.
Kim et al, 2013 <sup>18</sup>	30 Koreans (♂) – 17.2± 1.2	Cross-sectional	DXA	Spine, lumbar and femur	Judo	Judo significantly improves bone health during the growth period in male adolescents. Judo is strongly recommended to improve and prevent osteopenia in young/Korean men.
Nasri et al, 2013 <sup>6</sup>	50 + 30 Tunisian controls (♂) – 17.08± 0.2 years + control 17.1± 0.4 years	Cross-sectional	DXA	Spine and lumbar	Judo, Karate, Kyokushinkai Karate, Kung Fu and Boxing	Osteogenic effect of combat sports, especially judo and kyokushinkai karate. Children and adolescents may be encouraged to participate in combat sports.
Nasri et al, 2015 <sup>7</sup>	50 + 30 Tunisian controls (♂) – 17.08± 0.2 years + control 17.1± 0.4 years	Cross-sectional	DXA	Spine and lumbar	Judo, Karate, Kyokushinkai Karate, Kung Fu and Boxing	The practice of combat sports, in the early pubertal phase, has been shown to be the main predictor of BMD among adolescent athletes. It is more evident in the lumbar spine area. Also, they conclude that the practice of this type of sport contributes to optimal bone development.
Prouteau et al, 2006 <sup>21</sup>	68 French (♀♂) - ♀ Judo practitioners 20.9±3.4 years and control 20.1±1.0 / ♂ Judo practitioners 19±2.4 and control 19.5±0.9	Cross-sectional	DXA	Spine, lumbar and femur	Judo	The high osteogenic stimuli provided by the unique biomechanical judo environment can help prevent bone loss associated with weight loss interventions.
Shin et al, 2012 <sup>22</sup>	30 Koreans (♀) – taekwondo 17.2 ± 0.2 years and control 17.0 ± 0.2 years	Cross-sectional	DXA	Lumbar, femur	Taekwondo	The results of this study showed significant improvements for bone health in all weight groups. They suggest that taekwondo training during growth significantly improves bone health in female adolescents and is highly recommended to improve bone health and prevent osteoporosis in women.
Song et al, 2014 <sup>19</sup>	105 Chinese (♀) — 55-65 years	Longitudinal	DXA	Hips	Tai Chi, Walking, Dancing	They suggest that, as a fitness measure, Tai Chi is best for long-term exercising and its short-term effects are imprecise-ineffective compared to dancing and walking.
Woo et al, 2007 <sup>16</sup>	90 ♀- 90♂ Chinese - 65-74 years	Randomized	DXA	Spine, hips	Tai Chi, Resistance Exercise	They conclude that the beneficial effects of Tai Chi and resistance exercises on musculoskeletal health are modest and may not provide any better clinical outcomes.
Bolanowski et al, 2007 <sup>17</sup>	46 ♀ Polish – 27-75 years	Longitudinal	QUS AD-SoS	Phalanges	Tai Chi	They have found beneficial effects of regular Tai Chi exercise in older women evaluated by QUS. Tai Chi gymnastics is recommended for the prevention of osteoporosis
Chan et al, 2004 <sup>23</sup>	132 ♀ Chinese - 54.0±3.5 years	Randomized and prospective	DXA	Lumbar and femur	Tai Chi Chun	The first randomized and prospective 12-month TCC intervention (1 h/d, 4.2 times/week on average) revealed beneficial effects in the deceleration of bone loss in early postmenopausal women. In the long term, follow-up is needed to substantiate the importance of TCC in preventing osteoporosis and fall-related fractures.
Qin et al, 2002 <sup>24</sup>	PTCC 17 + 17 control ♀ Chinese – 50-59 years	Case control	DXA and pQCT	Lumbar, femur and distal tibia	Tai Chi Chun	A case-control study to show that regular TCC exercise may help delay bone loss in postmenopausal women.
Qin et al, 2005 <sup>15</sup>	211 ♀ Chinese – 50-65 years	Cross-sectional	DXA	Lumbar and femur	Tai Chi Chun	Regular TCC may be associated with higher BMD and better neuromuscular function in early postmenopausal women.

DXA = dual-energy X-ray absorptiometry. pQCT= peripheral quantitative computed tomography. BMC = bone mineral content. AD-SoS = amplitude dependent speed of sound. ♂ = male sex. ♀ = female sex. BMD = bone mineral density. QUS = quantitative ultrasound. TCC = Tai Chi Chun. TCCP = Tai Chi Chun practitioners.

did not present significant differences between the groups.<sup>4,7,15,16</sup> However, there are still few studies investigating the relationship between calcium intake and bone mass.

### Exercise: time of physical exercise, intensity and volume

Only four studies found significant values regarding the practice of sports and physical activity regarding exercise, duration, frequency, hours per week and number of years of practice of the sports discipline,<sup>5,7,17,18</sup>. However, three studies did not reveal any relationship with physical activity.<sup>15,16,19</sup>

### Smoking and Alcohol

A single study evaluated alcohol consumption and smoking among males (n=90) and females (n=90) of a Chinese community with Tai Chi practice and resistance exercise in which there was no statistical difference between the groups.<sup>16</sup> Due to the scarcity of studies directed to this topic, it does not provide any plausible explanation to discuss such result.

### Hormone 1: menopause, reproductive age and age of menopause

Four studies evaluated the variables that guide menopause to characterize their sample with Tai Chi Chum (TCC) and one control group.

he studies of Qin et al; Chan et al; Qin et al.<sup>15,23,24</sup> did not present statistical differences between the groups. However, the study by Bolanowski et al.<sup>17</sup> presented a negative correlation between the postmenopausal years and the groups. Despite the non-correlation between these variables, TCC provides several postmenopausal benefits, as it is a practice with no impact and with isometric exercises.<sup>23,24</sup>

## Hormone 2: cortisol, testosterone and bone markers

Three studies evaluated the hormonal aspects, such as cortisol, testosterone, growth hormone, alkaline phosphatase; C-terminal telopeptide of type I collagen (CTX); osteocalcin; n-terminal propeptide-procollagenase type 1 (P1NP).

Of these three studies, Nasri et al.<sup>6</sup> found that the explosive strength of the lower limbs was significantly higher in judo, karate and kyokushinkai karate practitioners than in boxers and in the control group, but with respect to the hormonal parameters (growth hormone and testosterone) there was no association between the combat groups and the control group. In another study, Nasri et al.<sup>7</sup> evaluated the bone formation markers alkaline phosphatase, CTX, osteocalcin and P1NP between combat athletes and a sedentary group. They found a significant difference between athletes and the sedentary group only in alkaline phosphatase and P1NP and the CTX values (bone resorption marker) were lower in combat athletes compared to the sedentary group.

In the third study, Prouteau et al.<sup>21</sup> found that in both sexes, cortisol levels were significantly higher in female judo practitioners than in controls, and total plasma protein concentrations did not reveal significant differences between the groups and sex.

Regardless of the results of the mentioned articles concerning hormones in groups of athletes (both males and females), the hormonal status is of the main and essential precursors for bone formation.

Studies evaluating efficacy in low-, medium- and high-impact sports have found significant changes in bone mass,<sup>4,9,23,25</sup>. However, those relating combat sports to bone mass are scarce. Of these, only three articles that discussed combat sports with assessment of bone mass using the DXA and QUS techniques were found in the literature.<sup>6,7,17</sup>

In summary, 15 studies were found with the topic addressed in this review.<sup>4-7,15-24, 26</sup> However, the small number of articles related to this theme requires further research to show the benefits of combat sports in bone health of healthy individuals of different ages, to better understand whether such changes play an important role in the development and maintenance of bone mass.

## CONCLUSION

Most studies conclude that the practice of combat sports presents significant improvements to bone health at all ages and is highly recommended to prevent osteopenia and osteoporosis. This review contributes to the scientific environment by encouraging the development of new research dealing with this theme, in order to understand the benefits of combat sports (of medium and high impact) in the prevention of bone diseases, especially in children.

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## REFERENCES

- Mora S, Gilsanz V. Establishment of peak bone mass. *Endocrinol Metab Clin North Am.* 2003;32(1):39-63.
- Gómez-Bruton A, González-Agüero A, Gómez-Cabello A, Casajús JA, Vicente-Rodríguez G. Is bone tissue really affected by swimming? A systematic review. *PLoS One.* 2013;8(8):e70119.
- Löfgren B, Dencker M, Nilsson J-Å, Karlsson MK. A 4-year exercise program in children increases bone mass without increasing fracture risk. *Pediatrics.* 2012;129(6):e1468-76.
- Andreoli A, Monteleone M, Van Loan M, Promenzio L, Tarantino U, De Lorenzo A. Effects of different sports on bone density and muscle mass in highly trained athletes. *Med Sci Sports Exerc.* 2001;33(4):507-11.
- Drozdowska B, Münzer U, Adamczyk P, Pluskiewicz W. Skeletal status assessed by quantitative ultrasound at the hand phalanges in karate training males. *Ultrasound Med Biol.* 2011;37(2):214-9.
- Nasri R, Hassen-Zrour S, Rebai H, Fadhel-Najjar M, Neffeti F, Bergaoui N, et al. Grip strength is a predictor of bone mineral density among adolescent combat sport athletes. *J Clin Densitom.* 2013;16(1):92-7.
- Nasri R, Hassen-Zrour S, Rebai H, Neffeti F, Najjar MF, Bergaoui N, et al. Combat sports practice favors bone mineral density among adolescent male athletes. *J Clin Densitom.* 2015;18(1):54-9.
- Greene DA, Naughton GA. Adaptive skeletal responses to mechanical loading during adolescence. *Sports Med.* 2006;36(9):723-32.
- Tenforde AS, Fredericson M. Influence of sports participation on bone health in the young athlete: a review of the literature. *PM R.* 2011;3(9):861-7.
- Krahenbühl T, Gonçalves EM, Costa ET, Barros Filho Ade A. Fatores que influenciam a massa óssea de crianças e adolescentes saudáveis mensurada pelo ultrassom quantitativo de falanges: revisão sistemática. *Rev Paul Pediatr.* 2014;32(3):266-72.
- Ingle BM, Machado AB, Pereda CA, Eastell R. Monitoring alendronate and estradiol therapy with quantitative ultrasound and bone mineral density. *J Clin Densitom.* 2005;8(3):278-86.
- Liberati A, Altman DG, Tetzlaff J, Mulrow C, Gotzsche PC, Ioannidis JP, et al. The PRISMA statement for reporting systematic reviews and meta-analyses of studies that evaluate health care interventions: explanation and elaboration. *PLoS Med.* 2009;6(7):e1000100.
- Matsumoto T, Nakagawa S, Nishida S, Hirota R. Bone density and bone metabolic markers in active collegiate athletes: findings in long-distance runners, judoists, and swimmers. *Int J Sports Med.* 1995;18(6):408-12.
- Fidanza F, Gentile MG, Porrini M. A self-administered semi quantitative food-frequency questionnaire with optical reading and its concurrent validation. *Eur J Epidemiol.* 1995;11(2):163-70.
- Qin L, Choy W, Leung K, Leung PC, Au S, Hung W, et al. Beneficial effects of regular Tai Chi exercise on musculoskeletal system. *J Bone Miner Metab.* 2005;23(2):186-90.
- Woo J, Hong A, Lau E, Lynn H. A randomised controlled trial of Tai Chi and resistance exercise on bone health, muscle strength and balance in community-living elderly people. *Age Ageing.* 2007;36(3):262-8.
- Bolanowski M, Pluskiewicz W, Skrzek A, Bolanowski J, Adamczyk P. Beneficial effects of Tai Chi on women's skeletal status assessed by quantitative ultrasound at the hand phalanges: one-year follow-up study. *Adv Clin Exp Med.* 2007;16(5):675.
- Kim PS, Shin YH, Noh SK, Jung HL, Lee CD, Kang HY. Beneficial effects of judo training on bone mineral density of high-school boys in Korea. *Biol Sport.* 2013;30(4):295-9.
- Song QH, Zhang QH, Xu RM, Ma M, Zhao XP, Shen GQ, et al. Effect of Tai-chi exercise on lower limb muscle strength, bone mineral density and balance function of elderly women. *Int J Clin Exp Med.* 2014;7(6):1569-76.
- Bozkurt I. Effects of exercises on bone mineral density of proximal femour region among athletes of different branches. *Int J Phys Sci.* 2010;5(17):2705-14.
- Prouteau S, Pelle A, Collomp K, Benhamou L, Courteix D. Bone density in elite judoists and effects of weight cycling on bone metabolic balance. *Med Sci Sports Exerc.* 2006;38(4):694-700.
- Shin YH, Jung H.L., Kang H.Y. Effects of Taekwondo training on bone mineral density of high school girls in Korea. *Biol Sport.* 2011;28:195-198.
- Chan K, Qin L, Lau M, Woo J, Au S, Choy W, et al. A randomized, prospective study of the effects of Tai Chi Chun exercise on bone mineral density in postmenopausal women. *Arch Phys Med Rehabil.* 2004;85(5):717-22.
- Qin L, Au S, Choy W, Leung P, Neff M, Lee K, et al. Regular Tai Chi Chun exercise may retard bone loss in postmenopausal women: A case-control study. *Arch Phys Med Rehabil.* 2002;83(10):1355-9.
- Baroncelli GI, Federico G, Bertelloni S, Sodini F, De Terlizzi F, Cadossi R, et al. Assessment of bone quality by quantitative ultrasound of proximal phalanges of the hand and fracture rate in children and adolescents with bone and mineral disorders. *Pediatr Res.* 2003;54(1):125-36.
- Strong WB, Malina RM, Blimkie CJR, Daniels SR, Dishman RK, Gutin B, et al. Evidence based physical activity for school-age youth. *J Pediatr.* 2005;146(6):732-7.