Research Article

IJSEHR 2024; 8(2): 32-38

www.sportscienceresearch.com
Received: 09-03-2024
Accepted: 23-06-2024
DOI: 10.31254/sportmed.8202

The impact of neuromuscular exercise and Ca-Mg-Zn supplementation on ankle and knee injuries among taekwondo athletes

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Abstract

Objectives: This study explored the impact of neuromuscular training (NMT) and Ca-Mg-Zn supplementation on ankle and knee injuries among taekwondo athletes. Design: Randomized control trial Setting: Sadra club in Iran Participants: sixty elite male participants were randomly allocated to a control group (n = 15), an NME group (n = 15), a Ca-Mg-Zn (CMZ) group (n = 15), and an NME+CMZ group. Main Outcome: Ankle and knee injuries Measures: All participants were assessed respecting ankle and knee injuries using clinical examination, radiography, and magnetic resonance imaging. Results: All sixty participants experienced 111 ankle and knee injuries during the study. The most prevalent injuries were patellofemoral syndrome and ligament sprain or tear in the NME group (40%), ligament sprain or tear in the CMZ group (46.7%), twisted ankle in the NME+CMZ group (26.7%), and patella fracture, twisted ankle, and twisted knee in the control group (40%). The total prevalence of injuries in the NME+CMZ group (15.31%) was less than the NME (32.43%), CMZ (21.62%), and control (30.63%) groups, though the among-group difference was not significant ($P > 0.05$). Conclusion: Combined NME+CMZ intervention is more effective than NME and CMZ interventions in reducing ankle and knee injuries among taekwondo athletes.

Keywords: Strength training, Ankle sprain, Neuromuscular training, Mineral supplementation, Taekwondo.

INTRODUCTION

Taekwondo is one the most popular martial arts throughout the world and an Olympic game since 2012. Taekwondo athletes usually use heel or foot kicks and turn and jump techniques to obtain scores and win games [1] . They need to jump, have a turn in the air, give a kick at the goal, and land at an appropriate position. Therefore, the risk of injury is very high in taekwondo. Studies in this area show high risk of lower limb injuries, particularly the injuries of the knee and the ankle [2]. For example, a study on 79 taekwondo athletes reported that almost 50% of them experienced injuries, mostly ankle injuries (63%), during the four-year course of that study [3]. Another study on 183 young taekwondo athletes showed that the most common injury sites were the ankle (30.6%), the foot/toes (27%), and the knee (20.1%) [2].

The mechanisms of injuries in taekwondo are different. Attack and defense techniques are responsible for almost 58.6% of muscular strains and contusions and 20.7% of sprains and luxations [4]. Taekwondo athletes are also at risk for injuries due to the contact quality of their exercises, overtraining, inadequate neuromuscular functioning, and the physical disability of the musculoskeletal system [2, 5]. The other common contributing factors to injury in taekwondo include previous history of injury, age, limited flexibility, inability to maintain the normal mobility of the ankle and the knee, and loss of balance [3, 6]. The musculoskeletal injuries of the ankle and the knee, for any reason, are associated with 80% of sport-related complications and negatively affect the performance of the taekwondo athletes who want to have long-term performance. Besides physical injuries, taekwondo injuries are associated with emotional problems, self-esteem disorders, and mood disorders, which can negatively affect recovery, treatment, and rehabilitation. Athletes with delayed post-injury rehabilitation may experience long-term problems such as lack of strength, limited joint range of motion, and chronic pain syndrome. A study into foot and ankle injuries among athletes in 37 sports reported that they missed twelve days of participation in performance on average because of these injuries and the recurrence rate of the same injuries was 28% [7].

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Although escaping injuries in taekwondo is impossible, preventive strategies help reduce their frequency, intensity, and complications. Neuromuscular exercise (NME), which primarily focuses on the risk factors of injures (i.e., reduced strength, endurance, flexibility, and balance), may help reduce the risk of injuries. NME is a strength and fitness training which combines different resistance, balance, core strength, dynamic stability, agility, and plyometric exercises [8, 9]. A meta-analysis revealed that training programs which include NME may increase reaction time, agility, coordination, and endurance, and decrease the risk of lower limb injuries [10]. NME is also an effective treatment strategy for strengthening the neurophysiological entity of the joints to improve balance. It also improves involuntary motor responses through stimulating sensory signals and core mechanisms. Besides, improvement in the synchronization and synergy of the muscular activity pattern due to NME improves the dynamic stability of the joints and prevents lower limb injuries. A recent study showed that progressive NME significantly improves lower limb functioning and joint position sense among athletes with the functional instability of the ankle and thereby, can reduce the risk of ankle and knee injuries [11]. Another study also found that NME can be effective in significantly reducing injuries and reaction time among amateur female rugby players (Sikora). Furthermore, several studies reported the effectiveness of NME in significantly reducing the risk of common sports injuries and improving sports performance [12-14].

The effects of NME can be magnified through the adequate intake of minerals. The intake of minerals, particularly calcium (Ca), magnesium (Mg), and zinc (Zn), before NME can positively influence a wide range of metabolic and physiological processes. Ca, Mg, and Zn have significant roles in muscular contraction, normal cardiac rhythm, nerve impulse conduction, oxygen transport, oxidative phosphorylation, and bone health[15] . The use of a combination of minerals may produce more significant effects than single mineral therapy [16]. For example, the Ca of the Ca-Mg-Zn mineral compound maintains muscular strength, reduces the risk of injuries, and shortens recovery time [17], its Mg supports the function of the cardiovascular and the musculoskeletal systems, elevates energy level, and facilitates post-exercise recovery [18], and its Zn plays pivotal roles in cell repair, immune and endocrine function, oxygen transport, recovery, and injury prevention [19, 20]. Nonetheless, studies reported the inadequate intake of the essential minerals such as Ca, Mg, and Zn by athletes [21, 22], which may negatively affect their performance.

Although NME and mineral therapy may be effective in preventing ankle and knee injuries among taekwondo athletes, there are limited data about the best protocol for NME and mineral therapy [23]. Moreover, as far as we know, there is no comparative study respecting the effects of NME and Ca-Mg-Zn mineral therapy and there are limited studies into the effects of mineral supplements on the prevention or treatment of sports-related muscular injuries [24]. Therefore, more studies in this area are necessary [25]. We conducted the present study to explore the impact of NME and Ca-Mg-Zn supplementation on ankle and knee injuries among taekwondo athletes.

METHODS

Design

This randomized controlled trial was conducted in 2023. Participants were elite male taekwondo athletes who ranked 1–3 in national or international taekwondo games in the past 3–5 years before the study and had a five-year history of participation in the Taekwondo Premier League of Iran. They were selected from Sadra taekwondo club in Tabriz, Iran, through purposive sampling. All participants had an identical taekwondo training program and trainers and attended their two-hour taekwondo training sessions four times per week at 18:00–20:00 .

The G*Power software (v. 3.0.10) was employed for sample size calculation with these parameters: the *F* test with the constant effect of the analysis of variance, an effect size of 0.5, a power of 0.85, a confidence level of 0.95, a degree of freedom of 3.0, and a group size of 4. Accordingly, 54 participants were determined to be necessary. The final sample size was sixty—fifteen per group [26, 27].

Eligibility criteria were an age of 16–20 years, regular participation in taekwondo training sessions for more than six months before data collection, First Dan black belt, and no participation in other NME or dietary supplementation programs during the study, and no history of injury during the past three months. Exclusion criteria were three absences from taekwondo training sessions, one absence from the intervention sessions, and muscular injuries during the study.

We used group randomization with block sizes of four and eight to divide participants to four groups, namely a control group (n = 15), an NME group (n = 15), a Ca-Mg-Zn (CMZ) group (n = 15), and an NME+CMZ group (n = 15). A colleague who was not involved in the study generated random allocation sequence using the Random Allocation Software (RAS). The sequence was concealed using sixty identical opaque envelopes numbered 1–60. The first envelope was for the first participant and the last was for the last participant. The first author who implemented the intervention as well as all participants were blind to the allocation sequence until the envelopes were opened. Moreover, participants and their trainers were blind to the primary results of the study.

Outcome measurement

The main outcome of the study was the prevalence of seven types of ankle and knee injuries which needed medical care irrespective of their outcomes (such as absence from the training sessions or games). These injuries were ligament sprain or tear, tendon strain, patella fracture, ankle fracture, twisted ankle, twisted knee, and patellofemoral syndrome. The second and the third authors who were blind to the groups performed data collection. Before and after the intervention, all participants were assessed respecting ankle and knee injuries [3] using clinical examination, radiography, and magnetic resonance imaging. Participants with acute injuries were visited and examined by an orthopedic specialist. The medical care staff of taekwondo games assessed the mechanism of injuries through interviewing participants at the time of injuries. Participants' preferred leg for kicks was considered as the dominant leg through interviewing them.

Intervention

Study intervention was six-week NME in the NME group, six-week Ca-Mg-Zn supplementation in the Ca-Mg-Zn group, six-week combined NME and Ca-Mg-Zn supplementation in the NME+CMZ group, and neither NME nor mineral supplementation in the control group. In the NME and NME+CMZ groups, participants performed sixty-minute NME three times a week for six consecutive weeks. NME sessions consisted of five main exercises (Table 1) and were held four hours before the main taekwondo training sessions under the supervision of a trainer. The intensity of the NME was set at 15–17 using the 0–20 Borg Rating of Perceived Exertion.

Participants in the CMZ and the NME-CMZ groups took one Ca-Mg-Zn tablet (Omid Parsina Damavand, Tehran, Iran) with dinner for six consecutive weeks (35). Each Ca-Mg-Zn tablet contained Ca carbonate 1050 mg (RDA% = 105), Mg oxide 525 mg (RDA% = 131), and Zn oxide 15 mg (RDA% = 136). Ca-Mg-Zn is a dietary supplement that seems to improve muscular contraction, relaxation, and tone as well as psychological and cognitive functioning and hence, may help improve sport performance. Participants' adherence to Ca-Mg-Zn therapy was evaluated through counting the tablets they returned to us. They were asked to avoid using any other mineral supplement during the study

and document the side effects of Ca-Mg-Zn supplement and contact us in case of any serious side effect to receive the necessary care services. Moreover, an interview was held with each participant about his lifestyle habits, medical history, and foods consumed in the past three days.

Ethical considerations

The Ethics Committee of Shahid Madani University of Medical Sciences, Tabriz, Iran, approved this study (code: IR.AZARUNIV.REC.1402.015) and the Iranian Registry of Clinical Trials registered it (code: IRCT20160523028028N3). One week before group allocation, all participants were informed about the study aim, methods, benefits, and potential risks of the study and informed consent was obtained from all of them.

Statistical analysis

Statistical analyses were performed using the SPSS software (v. 16.0) and at a significance level of less than 0.05. The Shapiro-Wilk test was run to test data normality. Group comparisons were performed using the Chi-square test, the one-way analysis of variance, and the Bonferroni's test.

Findings

Seventy five male taekwondo athletes volunteered for participation in the study and sixty of them were selected and divided into four groups. All sixty participants completed the study (Figure 1). The mean of participants' age was 17.93±1.37 years and the mean of their body mass index was 22.46±2.53 kg/m^2 (Table 2).

None of the participants had ankle and knee injuries at the beginning of the study. In total, participants experienced 111 ankle and knee injuries during the study—36 injuries in the NME group (32.43%), 24 injuries in the CMZ group (21.62%), seventeen injuries in the NME+CMZ group (15.31%), and 34 injuries in the control group (30.63%). The most prevalent injuries were patellofemoral syndrome and ligament sprain or tear in the NME group (40%), ligament sprain or tear in the CMZ group (46.7%), twisted ankle in the NME+CMZ group (26.7%), and patella fracture, twisted ankle, and twisted knee in the control group (40%). Although the prevalence of all injuries in the NME+CMZ group was less than the other groups (15.3%), there were no significant differences among the groups respecting the prevalence of the injuries after the intervention ($P > 0.05$) (Table 3 and Figure 2).

DISCUSSION

To the best of our knowledge, this was the first study into the impact of NME and Ca-Mg-Zn supplementation on ankle and knee injuries among taekwondo athletes. Findings indicated the lower prevalence of ankle and knee injuries in the NME+CMZ group. This is in line with the findings of a study that reported the effectiveness of 30–40-minute once a week NME on knee injuries [28]. A meta-analysis also showed that NME was more effective than usual training in significantly improving static balance and motor function and reducing the risk of injury among individuals with chronic ankle instability [13].

NME increases joint stability, improves joint position sense and protective reflexes, and thereby, reduces the risk of ankle and knee injuries. A recent study showed that NME focuses on exercises that broaden motor skills, help athletes move their body according to their situational needs, boost their muscular strength, improve their agility, balance, and performance, and reduce their exposure to common injuries [10]. NME enables the central nervous system to use mechanoreceptors and neuromuscular coordination in order to activate muscular motor neurons and improve joint position sense with a specific and organized pattern [13]. It can also improve dynamic balance and ankle and knee range of motion and reduce the risk of lower limb sprains and injuries [29]. At the time of landing after a taekwondo technique, muscular activity plays significant role in determining tendon-muscle stability, while the preactivation of the muscles of the ankle and the knee plays significant role in maintaining joint stability. During balance and plyometric NME, athletes consciously (or unconsciously) increase the muscular activity of the ankle to get ready for landing, adapt to position change, and absorb the strike [30]. Moreover, NME improves deep sensation among individuals with ankle instability, stimulates mechanoreceptors in or around the joints, improves the sensitivity of neuromuscular receptors to joint position[31], improves functional ability, and reduces the prevalence of ankle and knee injuries [32]. Although there are different NME protocols, we selected a combined protocol consisted of agility, balance, plyometric, and strength exercises because combined NME protocols seem to be more effective in preventing sports injuries [33] .

Although study findings showed no significant differences among the groups respecting the prevalence rates of ankle and knee injuries after the intervention, the prevalence rates of the injuries in the NME and the control groups were more than the CMZ and the NME-CMZ groups and the highest and the lowest rates of injuries were in the NME and the NME+CMZ groups, respectively. It is evident that ergogenics are necessary to improve the positive effects of physical exercises, functional capacity during exercises, and adaptation to exercises. Ca-Mg-Zn supplement is necessary to facilitate oxidative adaptation, increase mitochondrial proliferation, and prevent the depletion of substrates such as glycogen in muscular fibers. A study highlighted that dietary supplements such as minerals are a type of ergogenics [34]. The combination of Ca-Mg-Zn supplement with NME can improve athletes' readiness for activity, motor function, and post-sport recovery, and reduce the risk of injury [35]. Besides, Ca-Mg-Zn supplement can increase exercise capacity and adaptation and the levels of testosterone and insulin-link growth factor 1 and thereby, improve recovery, anabolism, and strength during physical exercise [36] and reduce the risk of injuries. The consumption of Ca-containing supplements before physical exercise reduces bone destruction parameters during and after exercise, stabilizes the blood level of Ca, reduces parathyroid hormone response to exercise, protects the long-term health of the bones, and reduces the risk of bone stress and sports injuries [37] .

CONCLUSION

This study suggests that CMZ supplement combined with NME (consisted of balance, deep sensation, plyometric, and strength exercises) may be effective in preventing ankle and knee injuries among taekwondo athletes. However, further investigations are still needed to determine the impact of CMZ supplement and NME on body composition, muscular strength, and joint injuries among athletes.

Study limitations

This study had several limitations. First, we could not find any study for the purpose of comparison and in order to make firmer conclusion. Second, the sample of this study was rather small and consisted only of adult male taekwondo athletes. Therefore, large-scale studies on different age and gender groups and with longer intervention courses are recommended.

Acknowledgement

The authors of this study want to thank the taekwondo athlete who participated in the study and the authorities of the study setting.

Conflict of interest

The authors reports no conflicts of interest.

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Table 1: The NME protocol of the study

Procedures
A. Warm-up (10 minutes)
1. General activities: a. Jogging: 3 minutes; b. Backwards running: 3 minutes; c. Lateral shuffling: 1 minutes
2. Specific activities: a. Carioca (Knee over and back out): 1 minute; b. Potentiation (depth jump and walking lunges): 3–5 repetitions×2–3 sets for each of them)
B. Neuromuscular training (40–45 minutes, 3 exposures per week up to 6 weeks)
1. Mobility: a. Lunge to hamstrings dynamic stretch; b. Standing hip out; c. 90–90 hip stretch: 3 minutes
2. Stability and Proprioceptive exercises: a. Ap-chagi: it can be performed by the front or rear leg in a given stance keeping balance, closing or furthering the distance, controlling spatial positioning 12 repetitions×2 sets×60 seconds rest per set; b. Catching and throwing a basketball without putting the foot down 12 repetitions×2 sets×60 seconds rest per set; c. One legged stance with the knee flexed on balance board. Throw and catch a ball over head alone while maintaining balance 60 seconds×2 sets×60 seconds rest per set
3. Strengthening the core muscles: a. Dumbbell Split Squat (80% one-repetition maximum) 6 repetitions×2 sets×60 seconds rest per set; b. Dumbbell Thruster (80% one-repetition maximum) 6 repetitions×2 sets×60 seconds rest per set; c. Dumbbell Chest Press (80% one-repetition maximum) 6 repetitions×2 sets×60 seconds rest per set; d. Sit-up exercises 15 repetitions×2 sets×60 seconds rest per set.
4. Speed training: Running sets of 5 repetitions×20 m×30 seconds rest per set
5. Plyometric and dynamic movement training: a. Single leg hop/switch for 30 seconds ×3 sets×30 seconds rest per set; b. Jumping over 30–60 cm obstacle for 30 seconds×3 sets×30 seconds rest per set
C. Recovery and cool down (10 minutes)
1) Cycling recovery: The progressive recovery will help remove metabolic waste products from athlete muscles. Lightweight stationary bike was used for this purpose (AMH Fitness E110 stationary bike). 5 minutes
2) Stretches aim to cool down: Forward Fold 30 seconds; Standing Hamstring Stretch 30 seconds for each extremity; Standing Glute Stretch 30 seconds for each extremity; Chest opener 30 seconds; Standing Quad Stretch 30 seconds for each extremity around 5 minutes

Table 2: Group comparisons with regard to participants' age and body mass index

Groups	**n**	**Age (Years) Mean±SD**	**Weight (Kg) Mean±SD**	**Height (cm) Mean±SD**	**BMI (Kg/m²) Mean±SD**
Cal-Mag-Zinc	15	17.93±1.48	69.13±6.43	177.20±5.30	21.95±2.40
NME	15	17.86±1.45	68.66±5.42	175.3±5.96	22.39±2.25
Cal-Mag-Zinc+NME	15	17.73±1.38	69.33±6.35	177.46±6.55	22.07±2.52
Control	15	18.20±1.26	70.33±7.99	172.93±6.25	23.44±2.85
P value*		0.82	0.91	0.16	0.36

NME: Neuromuscular training; BMI: Body Mass Index; *: The results of the one-way analysis of variance

Table 3: Group comparisons with regard to ankle and knee injuries

Group / **Injuries**		**NME +CMZ N (%)**	**NME N (%)**	**CMZ N (%)**	**Control N (%)**	**P value***
Ligament sprain or tear	Yes	2 (13.3)	6 (40)	4 (26.7)	7(46.7)	0.20
	No	13 (86.7)	9 (60)	11 (73.3)	8(53.3)	
Tendon strain	Yes	2 (13.3)	4 (26.7)	6 (40)	3(20)	0.37
	No	13 (86.7)	11 (73.3)	9 (60)	12(80)	
Ankle Fractures	Yes	2 (13.3)	5 (33.3)	4 (26.7)	5(33.3)	0.56
	No	13 (86.7)	10 (66.7)	11 (73.3)	10(66.7)	
Patella Fracture	Yes	3 (20)	5 (33.3)	2 (13.3)	6(40)	0.33
	No	12 (80)	10 (66.7)	13 (86.7)	9(60)	
Twisted Ankle	Yes	4 (26.7)	5 (33.3)	2 (13.3)	6(40)	0.41
	No	11 (73.3)	10 (66.7)	13 (86.7)	9(60)	
Twisted knee	Yes	3 (20)	5 (33.3)	3 (20)	6(40)	0.52
	No	12 (80)	10 (66.7)	12 (80)	9(60)	
Patellofemoral syndrome	Yes	1 (6.7)	6 (40)	3 (20)	4(26.7)	0.18
	No	14 (93.3)	9 (60)	12 (80)	11(73.3)	

*: The results of the Chi-square test

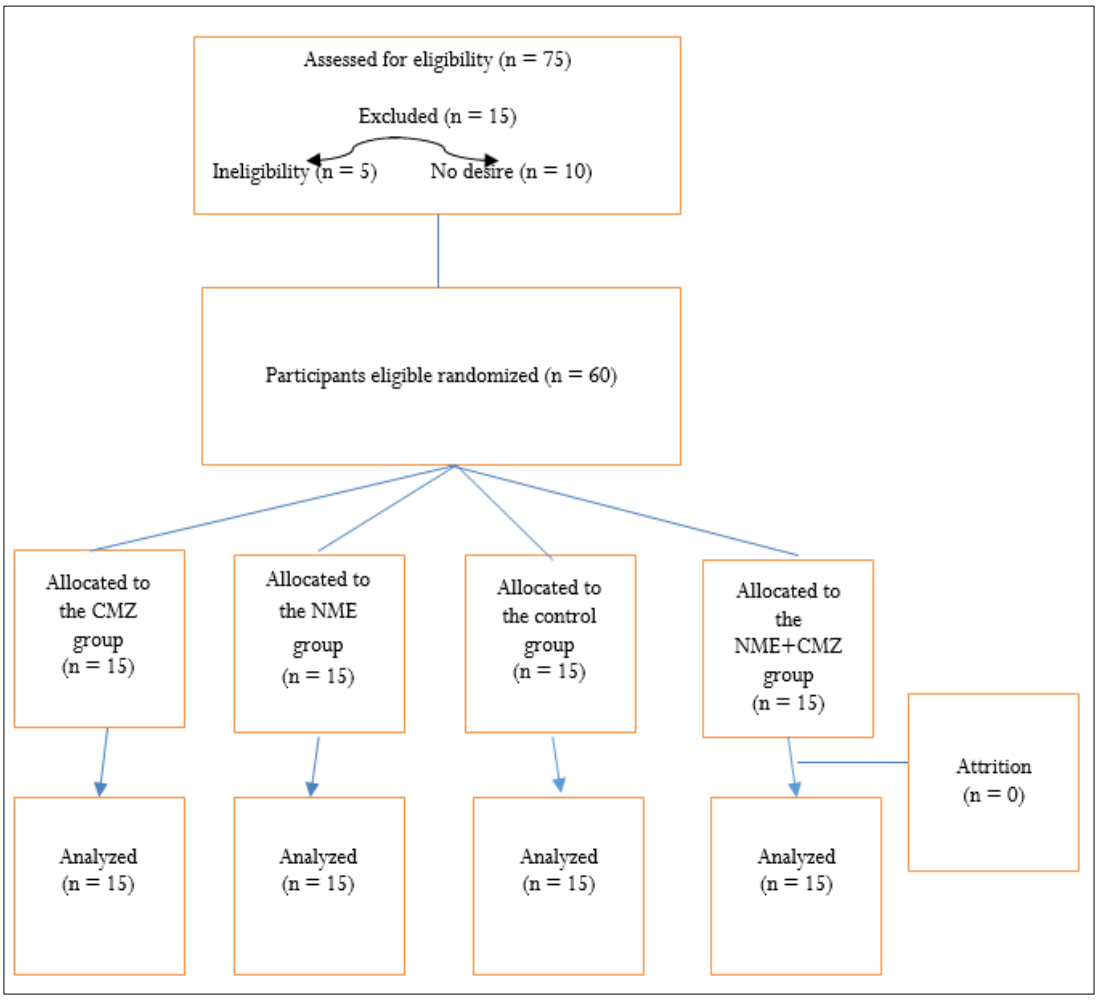

Figure 1: The flow diagram of the study

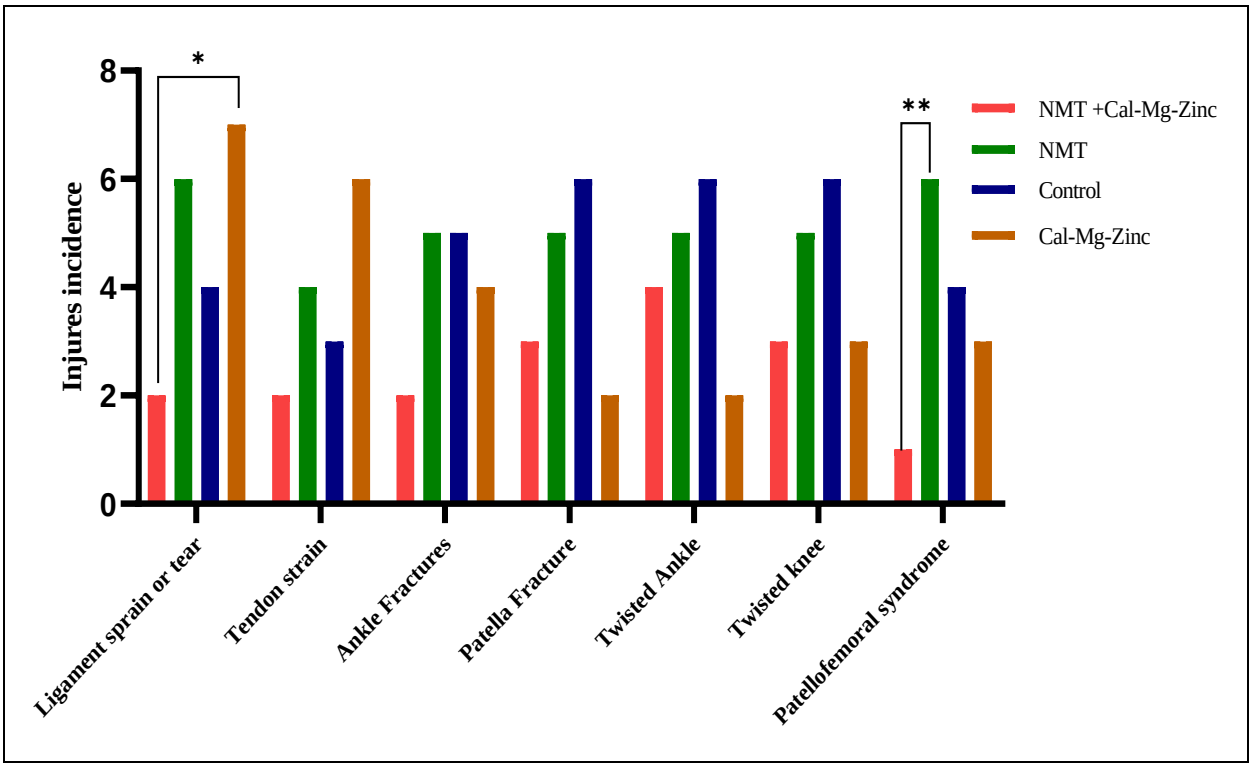

Figure 2: The prevalence of ankle and knee injuries in the four groups after the intervention

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