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Neuromuscular Control Training is Effective to Prevent Ankle Sprains in Athletes

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SUMMARY

Introduction. Lateral ankle sprain is the most common musculoskeletal injury in the physically active population and is highly prevalent in the general population. This study was conducted with the aim of investigating the effect of a course of neuromuscular control exercises on reducing risk factors for athletes prone to ankle sprains.
Materials and methods. In the present study, 30 male volleyball and basketball athletes with functional ankle instability were included-balance test scores and hop tests were used for evaluation. Data were analyzed using paired t-test and analysis of covariance.
Results. The results showed a significant relationship between Y-balance test scores and hop tests with neuromuscular exercises in the test group ($p < 0.05$). Neuromuscular exercises may improve Y-balance test scores and hop tests. Also, the results of the covariance analysis showed a significant difference between the intervention and control groups. By controlling for the pre-test effect, a significant difference was observed between the two groups ($p < 0.05$).
Conclusions. Neuromuscular exercises can be used to reduce risk factors for athletes prone to ankle sprains in settings with limited equipment.

KEY WORDS

Neuromuscular control training; hopping test; athletes; ankle sprain; Y-balance test.

INTRODUCTION

The ankle joint is exposed to serious injuries due to its importance in bearing weight and maintaining posture control during jumping, leaping and sudden change of direction exercises. So that, ankle joint injuries are the most common body injuries reported and in sports, including 25% of all injuries (1, 2). The external ligaments of the ankle plays the most important role in maintaining the bone structure and condition of the ankle joint and it is one of the most common vulnerable structures in athletes (3, 4). The risk of injury can act as a deterrent to future participation in athletic activities (5, 6). Lateral ankle sprain is the most common musculoskeletal injury in the physically active population and is highly prevalent in the general population. This prevalence is significant and leads to the cost of health care for injuries (7). The cost of treating and diagnosing lateral ankle sprains was estimated at approximately $4.5 billion in 2015, up from $2 billion in 1984. It also has a high prevalence rate of over 2.15 per 1,000 people per year and more than half of all ankle sprain injuries that are reported in high school and college games in the United States (8).

In football, basketball, volleyball and handball, ankle sprains are reported between 10-30%, and the most common type of injury is plantarflexion with inversion and adduction (9). The external ankle ligament complex is one of the most commonly injured structures in athletes. In such a way that external sprains include 85% of ankle sprains (10). Ankle injury is a major medical and socioeconomic problem, because the prev-

alence of ankle injuries is high and the cost of treatment and absence from work due to this injury is high (11).
Chronic ankle instability is one of the most common debilitating complications of acute ankle sprain, which usually leads to the athlete staying away from sports activities (12). In summary, factors like laxity of the ligaments, weak subtalar joints, poor proprioception and delayed muscle responses – especially due to past injuries – can compromise the ankle joint's stability and proprioceptive functions, predisposing it to this type of injury. Early intervention to address these issues may help prevent recurrences (13). Recently, conservative treatments of chronic ankle instability have been accepted as the main means of managing the condition and preventing re-injury, so that the effect of exercise therapy in reducing the risk of recurrence of ankle sprains and chronic ankle instability has been shown (14, 15).
Damage to the mechanoreceptors near the ankle sprained ankle can lead to functional deficits, deficits in postural control and postural control, deficits in strength, range of motion, and chronic instability from the initial injury (16-18). In this regard, Ganesh *et al.* (2015) pointed out the negative impact of ankle sprain injury on performance (19). About 40-75% of people have experienced functional instability after ankle sprain. The high prevalence of functional instability after ankle sprain is alarming because instability is one of the known factors for secondary osteoarthritis. Repeated ankle sprains can also cause arterial damage (anterior tibia artery and posterior tibia artery). It has been observed that the defect in postural control and the reduction of performance following ankle sprains are the result of ankle functional instability. The role and importance of posture control is determinant in the daily life activities and performance of people, especially athletes, in such a way that the resulting instability causes disturbances in posture control and performance (20). Posture control and performance are not separate from each other, because postural control is the source of all conscious movement skills of people (21). Although posture disorder is not evident in athletes, the smallest change in their posture control results in a malfunction. Freeman *et al.* (1965) suggested that coordination exercises can effectively improve postural control and reduce the risk of recurrent ankle sprains in individuals with CAI. Therefore, incorporating coordination exercises into rehabilitation programs for individuals with CAI may be beneficial in improving their overall ankle stability and reducing the risk of future injuries (22). In another one, Shokouhi *et al.* (2015) compared the postural stability of soccer players with and without CAI (chronic ankle injury) in the functional test of landing jump in soccer players. They found that in the forward jump, the displacement variables of the center of pressure in the internal-external and anterior-posterior directions in soccer players with CAI were significantly higher than in healthy players, which reduces the efficiency and performance of athletes (23). Ankle injury is a major medical and socio-economic problem because the prevalence of ankle injuries is high and the cost of treatment and absence from work in this injury is high (4). Because ankle injury, in addition to the need for long breaks after the injury, which requires 2 to 4 months of rest for full recovery, also imposes a lot of costs on the subject. According to the mentioned cases, the sensitivity and importance of correct treatment and prevention of ankle injuries in athletes are more important and vital. Therefore, the goal of correctional and rehabilitation programs is to prevent and treat ankle injuries, correct or eliminate risk factors, and ultimately reduce injuries. Modifiable risk factors are neuro-muscular and biomechanical risk factors that can be modified with special sports exercises such as deep receptor exercises, neuromuscular exercises, stretching, plyometric and trunk and central muscle control exercise (24). Ankle mobility provides a buffer during landing and peroneus longus activation prevents ankle inversion. During the jump and landing, adaptation to the landing force and control of neuromuscular activation are very important in maintaining ankle stability. Together, they can effectively minimize the risk of ankle sprain injuries (25).
A set of plyometric exercises and a dynamic training method for the lower limb are hopping exercises which has the multiple nature of muscle strength, neuromuscular coordination, joint stability, balance and joint proprioception. Muscular strength and balance are two essential components of jumping performance. Hopping exercises cause neuromuscular adaptation and thus lead to increased performance and faster and more powerful execution of movements (26, 27). In a study Minoonejad *et al.* (2018) found that six weeks of hopping stabilization training was effective in improving neuromuscular control and self-reported performance in collegiate basketball players with ankle instability (28). Also, it seems that six weeks of jumping training reduces the time interval before starting the activity and increases the range of activity of the internal gastrocnemius and gluteus Maximus muscles in one-legged jump landing in athletes with functional ankle sprain (29). In general, neuromuscular control has a large effect on ankle sprains. For people with CAI, the quality of their joint movement patterns and muscle activity is somewhat compromised. However, they can still perform high-intensity exercise with satisfactory coordination and control strategies among their joints and muscles. Accordingly, in addition to facilitating the strengthening of the peroneus longus to train muscle recruitment and reduce the occurrence of inverted sprains, muscle groups around other joints should be strengthened to provide optimal landing patterns for individuals with CAI (25).
Over the past decade, ankle exercises have been at the core of developing exercise programs aimed at preventing and recur-

ring ankle sprains. Previous researchers have focused more on rehabilitating activities that do not replace functional tasks, such as open chain activities, static activities, and reaction time. This focus makes it difficult to compare results to weight-bearing activities that occur during most ankle sprains. Therefore, the present study was conducted with the aim of investigating the effect of a course of neuromuscular control exercises on reducing the risk factors of athletes prone to ankle sprains.

MATERIALS AND METHODS

This research has been conducted in the form of research plan No.140007065665 and ethics code is IR.UMSHA.REC.1400.487 (Hamadan University) – date of approval: November 09, 2021.

Research method

This interventional study on young athletes (n = 30), male members of volleyball, basketball, and handball teams, with an age range of 18-25 years, with ankle sprains (30).

Athletes were randomly assigned to two intervention and control groups. To randomize the patients, the random block method with a block size of four was used. For this purpose, four sheets of paper were prepared. The letter I (test group) was written on two sheets and the letter C (control group) was written on the other two sheets. The sheets were mixed together and removed by the researcher consecutively without placing them. This process was repeated for the number of qualified people and the group of each subject was determined. The subjects of the test group performed hopping exercises for six weeks and three sessions a week. The inclusion criteria included being an athlete, having functional instability of the ankle, without any deformities affecting the research process (such as kyphosis, scoliosis, and sway back, uneven shoulder) and completing the consent form to participate in the research. The exclusion criteria for the participants were the age group above the purpose of the study, lack of consent to cooperate in the research process, and any pain during the work process.

Data collection and evaluation method

Ankle Joint Functional Assessment Tool (AJFAT) was used to identify people with ankle sprains. Participants selected responses that best described ankle use using the following scale: much less than the other ankle, slightly less than the other ankle, equally, slightly more than the other ankle, or slightly more than the other ankle. Each answer is assigned a point value between 0 and 4. The values of the scores were unknown to the participants. The maximum score in this evaluation tool is 48. Experimental data show that AJFAT has test-retest reliability (internal correlation coefficient 0.94) and precision (standard error of measurement 1.5) (31).

To evaluate the dynamic balance, the Y test was taken from the instability leg. In this way, the subject without shoes, stood in the center of a grid of lines measured by a Y tape measure. The lines extend from the center in three directions: anterior, posterior, internal, and posterior external, so that they form a 90-degree angle in the posterior direction and a 135-degree angle with the anterior direction. The subject's foot was set in the center, so that the big toe of the subject's foot was placed in the starting line of the center (**figure 1**). After setting the subject's foot in the center, he was asked to stand on his foot and gently touch each of the lines on the floor with the tip of the big toe of his other foot as far as possible. The test was performed three times in each direction and the maximum reach distance was considered as the raw score of the reach distance in each direction. The total average of the maximum reaching distance of the subject in each direction was divided by the length of the lower limb and then multiplied by 100, and it was considered as the normalized composite score of the subject's balance as a percentage.

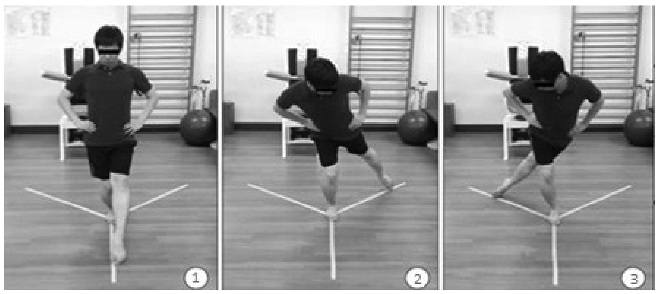

Figure 1. How to perform the Y test in anterior, posterior, internal, and posterior-external directions.

A tape measure with an error of 1% was used to measure the length of the lower body. The actual length of the foot was measured from the upper anterior metatarsals to the medial ankle using a tape measure. For this purpose, the subject was placed in supine position, while the knees were in extension and the feet were 15 cm apart. The measurement on the left and right leg was repeated three times and the average of each was recorded as the length of the lower body (32). Then, the hopping test (single leg jump test, single leg cross jump, triple jump and single leg duration test) was taken from the subjects (**figure 2**).

Hopping test (33)

Single Hop test

The subject stands on the test leg and performs the hopping with one leg as far as possible and lands with the same leg, and the amount of distance achieved is recorded.

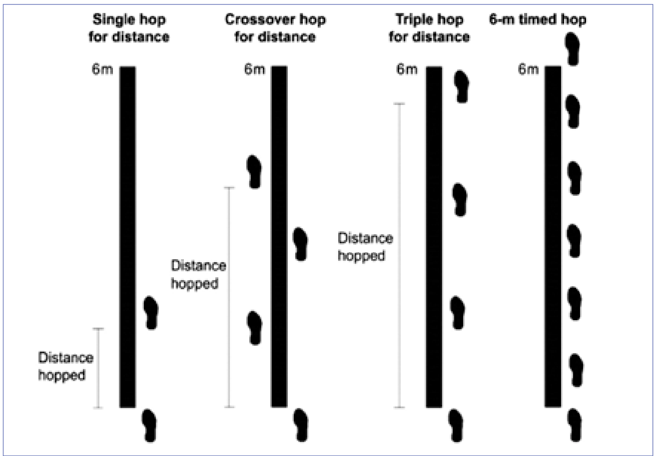

Figure 2. Hopping test.
Adapted from reference (33).

Crossover Hop test
The subject stands on the test leg and performs hopping on a 15 cm wide line in a crossover pattern as far as he can for 3 hops and finally hopping distance is recorded.

Triple Hop test
The subject performs three consecutive hopping as far as he can and finally the distance covered is recorded. Three tests recorded when the subject's attempt is successful and has stable landing. In order to achieve legitimate and correct efforts, one's landings must be successful and controlled. If the subject lands with the other foot, loses balance control, or has an extra hop after landing, the attempt must be repeated. The subject is asked to start the tests with the big toe on the floor just behind the starting line. The distance of hop tests was evaluated by a tape measure as the closest distance from the starting line to the back of the subject's heel.

6-min timed Hop test
The subject was stranded on a leg and performed the hopping in a 6-meter path that has been marked in advance. He was asked to travel this route as fast as possible and the time to travel this six-meter route is recorded for him using a stopwatch. The time was recorded from the time the subject's heel leaves the ground until the subject crosses the finish line. The training program includes 6 types of hopping exercises: hopping to the sides, hopping to the front and back, hopping in the form of four Latins, hopping moving forward, hopping in the form of eight Latins (**figure 3**), which is three sessions a week and it was done for six weeks. The intensity of the exercises increased from 80 to 160 feet contact with the ground during the weeks. Also, the exercises were performed on two legs and then on one leg, and the position of the hand was changed from the free position to the chest and behind the head to increase the difficulty and intensity of the exercises. Also, the level of training every week was changed from the floor of the hall to the surface of artificial grass and training mat. In the first three weeks, exercises were done in the form of hopping and stability (18) and from the third week onwards, hopping exercises were performed with a rhythm of 2 Hz using a metronome (34).

Data analysis
The effect of neuromuscular exercises on the scores of the Y test of the lower limb and the hop test between the pre-test and post-test stages was investigated separately for each of the test and control groups using the paired t-test. Also, analysis of covariance test was used to compare the Y test score between the test and control group by controlling the pre-test effect. Data analysis was done using SPSS version 19 software at a significance level of 0.05.

RESULTS
A total of 30 athletes were studied. These athletes were randomly divided into two groups of 15 people. The mean athletes' age was 35.22 (standard deviation (SD) 55.3) years in the test group and 14.22 (SD 84.3) in the control group. The basic characteristics of the athletes, separated from the test and control groups, are presented in **table I**. As can be seen, the basic characteristics in the two groups are almost similar.

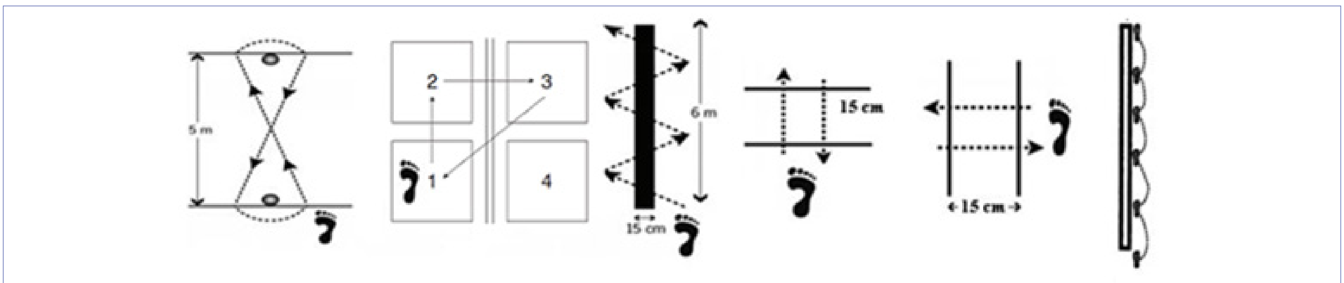

Figure 3. Hopping exercises.
Adapted from reference (45).

Table I. Average and standard deviation of age, height and weight of subjects.

Variable	Group	Number	Average	Standard deviation
Age (years)	Test	15	35.22	55.3
	Control	15	14.22	84.3
Height (cm)	Test	15	53.178	09.6
	Control	15	84.177	93.6
Weight (kg)	Test	15	42.71	20.5
	Control	15	73.70	69.5

The comparative pre and post-test results in each group using a paired t-test are presented in **table II**. The results showed that significant differences were observed between the pre- and post-test in the test group for test score Y (p = 0.0001), Single Hop test (p = 0.038), Crossover Hop test (p = 0.0001), Triple Hop test (p = 0.003), and 6-min timed Hop test (p = 0.002). However, in the control group, there were no significant differences in all of the studied variables (p > 0.05).

The results of covariance analysis (**table III**) showed that there is a significant difference between the test and control groups by controlling the pre-test effect (p < 0.005). So that the mean scores of Y test, single hop test, crossover hop test and triple hop test of athletes prone to ankle sprain in the test group increased compared to the control group. Also, the mean score of the 6-minute timed hop test of athletes prone to ankle sprains in the test group has decreased compared to the control group (p < 0.05).

DISCUSSION

The present study was conducted with the aim of investigating the effect of neuromuscular control exercises on reducing risk factors in athletes prone to ankle sprains. The results showed that neuromuscular exercises significantly improved the scores of the Y test and the hop test of athletes prone to ankle sprains between the pre-test and post-test stages (p < 0.05). Among the studies, in line with our results there is the Kordi Ashkezari *et al.* (2020) study, which aimed to compare the effect of 6 weeks of balancing and hopping strengthening training on the kinematics of the lower extremities of athletes with functional ankle instability while running. The study found that hopping training in dorsiflexion, ankle inversion, and knee flexion were significantly different from the control group. The results showed that both hopping and balance strengthening training improved the dorsiflexion, inversion, and knee flexion angles at the initial contact during running. However, hopping exercises were found to be more effective than balance strengthening in improving knee flexion angles. In addition, a significant difference was observed between the two groups of strengthening/balance training and hopping, increasing knee flexion. They found that the role and importance of posture control is very important in the daily life activities and performance of people, especially athletes, in

Table II. The results of the effect of neuromuscular exercises on the Y test score of the lower limb and the test score separately for each of the test and control groups.

Hope test score	Group	Pre-exam	After the test	P-value
		mean ± SD	mean ± SD	
Test scoreY	Test	21.11 ± 1.97	76.25 ± 1.99	0.0001
	Control	14.03 ± 1.98	14.51 ± 1.97	217.0
Single Hop test	Test	95.66 ± 14.106	13.06 ± 15.131	038.0
	Control	93.06 ± 13.107	73.06 ± 12.113	458.0
Crossover Hop test	Test	53.73 ± 24.361	99.80 ± 29.386	0001.0
	Control	94.60 ± 23.356	01.93 ± 22.363	434.0
Triple Hop test	Test	21.06 ± 28.470	78.33 ± 29.511	003.0
	Control	88.33 ± 36.474	16.06 ± 36.485	137.0
6-min timed Hop test	Test	24.12 ± 0.3	32.75 ± 0.2	002.0
	Control	23.08 ± 0.3	27.99 ± 0.2	223.0

SD: Standard deviation.

Table III. The results of covariance analysis to compare the Y test score between the test and control groups.

Hop test score	Sum of squares	Degrees of freedom	Mean square	Statistic f	P-value	Effect size
Y test score	09.29	1	09.29	26.14	001.0	346.0
Single Hop test	362.412	1	362.412	22.12	002.0	312.0
Crossover Hop test	914.345	1	914.345	43.6	017.0	192.0
triple Hop test	375.448	1	375.448	93..4	035.0	155.0
triple Hop test	50.0	1	50.0	15.6	020.0	186.0

such a way that the resulting instability causes disturbances in posture control and performance (35). Shahverdi *et al*. (2019) investigated the effect of neuromuscular exercises on balance symmetry in people with chronic ankle sprains. The results of their study, in accordance with our results, showed that ankle sprains cause balance asymmetry in both legs and that neuromuscular exercises improve this balance. Both legs and balance asymmetry compensation. After one month without training, balance symmetry was maintained in both legs (36).

In a study similar to ours, Hung (2015) investigated neuromuscular control and rehabilitation in people with chronic ankle injury, he stated that injury and lateral dislocation of the ankle is one of the common problems in athletes, and after decades of research, the main causes of sprains have not yet been fully explained. He concluded that which exercise method improves the effects and factors of re-injury in people with chronic ankle injury is still unclear (37). In their study, Fahim (2015) examined the effect of four weeks of neuromuscular training on the static balance of men and women with chronic ankle instability. Thirty subjects were divided into two experimental (7 women and 8 men) and control (7 women and 8 men) groups of 15 people. The results of this study showed that a course of neuromuscular exercises caused a significant improvement in the static balance of the experimental group. They concluded that neuromuscular exercises can be used in people with chronic ankle instability to improve posture control (38).

Many rehabilitation studies have been conducted to evaluate the effects of neuromuscular control, sometimes proprioceptive, as a method of increasing muscle and nervous system sensitivity because ankle sprains cause muscle weakness and loss of neuromuscular function, but the loss of neuromuscular function is more pronounced than the loss of strength (39). In a similar study, Tarang *et al*. (2014) investigated the effects of balance training for 4 weeks on patients with functional ankle instability. The results of their study indicated that after completing the training period, ankle instability is reduced and ankle joint proprioception is improved as a result of the effectiveness of exercises in patients. Therefore, the use of these exercises can be useful for people suffering from ankle functional instability (40).

The second main finding of this research was the results of covariance analysis between the two test and control groups, which showed a significant difference, so that by controlling the effect of the pre-test, a significant difference was observed between the two groups. The hop test is suitable for testing lower limb function in patients with ankle sprains and has been reported to be very reliable and valid (41, 42). This study also determined that the average score of the Y test, single hop, crossover hop and triple hop of athletes prone to ankle sprain increased significantly compared to the control group. Also, the average score of the 6-min timed hop test of athletes prone to ankle sprains has significantly decreased compared to the control group. In this regard, Karimizadeh *et al*. (2013) investigated the effect of six weeks of hopping exercises on the dynamic balance of athletes with functional ankle instability. The number of 30 male athletes, including two experimental and control groups, the experimental group underwent training for six weeks. Dynamic balance was evaluated by the star test. The results showed that hopping exercises caused a significant increase in the subject's reaching distance in all eight directions of the star test. They recommended that due to the special need of people with ankle functional instability for dynamic balance in sports skills and also as an important rehabilitation factor in the design of exercise and rehabilitation programs, the benefits of the hopping training program should be used. Additionally, they recommended incorporating balance and proprioceptive exercises into a rehabilitation program can help reduce the risk of future ankle injuries and improve overall ankle function. Therefore, it is important for individuals with ankle functional instability to work with a physical therapist or sports medicine professional to develop a comprehensive exercise program that includes hopping and proprioceptive exercises to improve dynamic balance and stability (26, 30).

There are several methods of conservative treatment for ankle problems, such as rehabilitation exercises and physical therapy. These treatments have a positive effect, and it is difficult to determine which method is superior. Research directly comparing different treatment modalities is limited (43). Although this study and others have shown positive effects of neuromuscular training, the effectiveness of balance exercises along with neuromuscular exercises cannot be ignored. However, experts explain that it is possible to prevent injury through balance training, and more results are being published for injury prevention programs that incorporate the principles of balance training alongside neuromuscular training (44).

As with all studies, this study had limitations. The impossibility of investigating the daily life activities of participating athletes was one of the limitations of the research, and the researcher was confident about its results. Also, the researcher has conducted this research based on the available statistical population, which can be expanded in future studies.

This study was conducted in order to investigate the effect of an effective training method to reduce the risk factors of ankle function following frequent ankle injuries in people who attend in jumping sports and to test the effectiveness of hopping exercises.

CONCLUSIONS

Chronic ankle instability is one of the most common disabling complications of acute ankle sprains. Which usually leads the athlete to stay away from sports activities. Based on these results, we recommend practical applications of hopping exercises to rehabilitation professionals. Rehabilitation experts may be able to provide both or one program (neuromuscular and balance) according to the needs and characteristics of the patient, especially in places where there is not enough equipment. Furthermore, much of the data on injury incidence and prevalence of musculoskeletal conditions among athlete populations from high-quality surveillance systems is focused on the most popular and highly populated team sports, such as basketball, football, and soccer. More research is needed on other similar activities and sports. It may be particularly important to evaluate the incidence of ankle sprains and the effect of neuromuscular exercises among athletes of other age groups.

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DATA AVAILABILITY

Data are available under reasonable request to the corresponding author.

CONTRIBUTIONS

The authors contributed equally to this work.

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CONFLICT OF INTERESTS

The authors declare that they have no conflict of interests.

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