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Research Article

Assessing the Benefits of Neuromuscular Training in Preventing Sports Injuries: A Physiotherapy Approach

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Abstract

This study set out to evaluate the efficacy of NT in mitigating the risk of the students and other sportsmen and women of collegiate and amateur soccer, basketball, and volleyball teams with sports injuries. The study design used was a randomized controlled trial with 100 participants, 50 males and 50 females aged between 18 and 35 years. The subjects were divided into the NT group, which exercised three times a week for 12 weeks with NT, and the control group, which trained as they usually did. The main objective was to capture the number of lower limb injuries and the secondary objectives involved capturing joint stability, proprioception, and functional performance. The NT group had a 12% incidence of injury while the control had a 30% incidence; chi-square = 8.43, $p = 0.004$. Further, the NT group recorded significant changes in joint stability, as measured by the anterior drawer test ($p < 0.001$) and proprioception using a balance board ($p < 0.001$). In addition, functional performance measures such as the vertical jump height, agility, and one-rep max squat all improved significantly ($p < 0.001$). Hence, the study shows that the assimilation of NT in athletic training could help prevent acts of injuries and propel the performance of athletes.

Keywords: Neuromuscular training, sports injuries, randomized controlled trial, joint stability, functional performance, injury prevention.

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Introduction:

Participants in sporting activities, whether engaging in leisure-time exercise, competing as professional athletes, or representing a sports team, experience a range of physical and psychological effects. Such injuries affect persons who engage in sporting activity and this has led to physical, mental, and financial loss. According to the Centers for Disease Control and Prevention (CDC), it was estimated that about 7.7 million sports and recreation-related injuries occur each year in the US, and the majority of these victims are aged between 5 and 24 years (Rui et al., 2019). Sports injuries may be acute or chronic and may range from mild to severe including sprains and strains, ligament ruptures, fractures, and concussions. Some of the general sports injuries include soft tissue injuries, bone injuries, joint injuries, and overuse injuries (Bhardwaj, 2013). They are usually a result of poor biomechanics, excessive training poor warm-up, or accidents such as falls or impacts. Sports-related injuries differ in frequency and prevalence reflecting the type of the sport; contact sports football and rugby have a higher prevalence of injuries as compared to non-contact sports like swimming and cycling. Gender age and level of training, are also considered important predictors of the risk of an injury, whereby females and adolescent athletes are found to be at a higher risk of incurring certain particular types of injuries including ACL injuries (Griffin et al., 2006).

There has been a rise in the last couple of years in the need to cohort the prevention of sports injuries because prevention of sports injuries can go a long way in ensuring that athletes better the health of the athletes, improve performance, and have long-lasting careers. The conventional methods of injury prevention are strength and conditioning, warm-up, and biomechanics (Hewett et al., 2016). However, recent studies have indicated that NT, a specific training technique that focuses on the CNS-muscular system interaction, could be highly effective in the prevention of numerous sports-related injuries especially those of the lower limbs.

This indicates that NT is a useful method of training notably the neuromuscular, joint stability and movement (Mandelbaum et al., 2005). The primary aim of NT is to enhance the output of the nervous system to the muscles, muscle contraction, co-contraction, proprioception, and velocity. This incorporates strength, balance, agility, and plyometric training to enhance correct biomechanics and decrease the risk of injury (Myer et al., 2014). This is the reason why neuromuscular training is being considered in the prevention of sports injury because it addresses modifiable risk factors more specifically knee and ankle injuries. For instance, Hewett and his colleagues have established that neural control of movement joint moments and trousseau that is regarded as dynamic stability during activities such as jumping and landing puts the ACL in a vulnerable position to be injured. Neuromuscular training is very useful for this as it assists the athletes on how one can learn how to land, position the body, and contract the right muscles during any dynamic movement to reduce the loads placed on the knee joint (Hurd & Snyder-Mackler, 2007).

Besides, the program has also been used as a tool to prevent ankle sprains and other lower extremity injuries. A systematic review by Emery et al. (2015) found that athletes who conducted neuromuscular training programs had their incidence of ankle sprains reduced as compared to those who did not have the training. This is because NT offered improvement in balance, proprioceptive information, and muscle synergies.

In addition, neuromuscular training has advantages that go beyond the protective effect against injuries. Myer et al, (2014) has also stated that the athletes who take part in NT programs also show enhanced performance as perceived by speed, power as well as agility. In this way, NT is not only a preventive method but also a method of increasing the effectiveness of work, which makes it possible to consider it as an attractive intervention for athletes of various types of sports.

Several good-quality trials have confirmed the use of neuromuscular training in the prevention of injuries. Mandelbaum et al. (2005) in a classic study showed that a neuromuscular training program decreased the number of ACL injuries in female soccer players in two seasons. Also, Hewett et al. (2010) affirmed that female athletes who went through the neuromuscular training program had a lower rate of ACL injuries compared with the group of athlete females who did not. These findings have led to the incorporation of neuromuscular training into different sports training programs, especially for high-risk lower extremity injury athletes.

Nevertheless, the available literature on the efficacy of neuromuscular training means that it is not yet incorporated into all programs aimed at injury prevention. One disadvantage is that a significant amount of time and energy must be invested to deliver NT programs effectively, which means coaches and athletes will not take this approach. In addition, some of the sports professionals interviewed may not know the benefits of NT or have other forms of prevention that they prefer to NT such as strength training or stretching (Webster & Hewett, 2018).

Hence, many injuries occur in sporting activities especially those of the lower limb, thus steps must be taken to ensure the prevention of such accidents. Prevention incorporates neuromuscular training because it minimizes the risk of injury by improving the neuromuscular control, balance, and proprioception of athletes (Caldemeyer et al., 2020). The study about the NT has gained more support from research to show that particularly in the prevention of ACL and ankle sprain, it will also be appropriate to be used as part of the injury prevention program. Regarding both athletic performance and the medical-related sciences, it is also deemed paramount to prevent injuries and due to the lack of research on the real incorporation of NT, there is a potential integration to further protect and improve the safeguard of athletes.

Materials and Methods

Study Design:

This research work used a randomized controlled trial (RCT) design to compare the efficacy of neuromuscular training (NT) in averting sports injuries. The random allocation technique divided patients into the experimental group (NT) and the control group. The trial was carried out for one year with an assessment of injuries and performance measures at 3-month intervals. These follow-ups enabled the relative distinction between the incidences of injuries, biomechanical changes, and variations in the functional potential. All the research was carried out under the institutional ethics committee, and the subjects agreed to participate in the research by giving their written consent. This trial was conducted following the Helsinki Declaration and standards for clinical experimentation in sports and exercise sciences.

Participants:

The participants for the study were 100 in number. Only those participants who met the inclusion and exclusion criteria were selected to maintain the homogeneity and appropriateness of the sample.

Inclusion and Exclusion Criteria:

The inclusion criteria for the participants included; being in the age group of 18 to 35 years, participating in competitive soccer, basketball, or volleyball at the collegiate or amateur level, having no history of severe lower limb injury in the previous year before the study, being fit for physical training and willingness to give informed consent to participate in the study. On the other hand, participants were excluded if they had a current musculoskeletal injury, a history of neurological conditions, were participating in a structured neuromuscular exercise program before enrollment, or if they could not or would not meet the study requirements or provide informed consent.

Protocol:

The neuromuscular training (NT) protocol involved balance, plyometric, and strength training in the lower limbs' proprioception. In the experimental group, participants attended training sessions that lasted for 60 minutes, 3 times a week for 12 weeks. The exercises gradually became more complex from basic balance exercises to more dynamic and sport-related movements.

The exercises that were included in the experiment program were chosen to enhance neuromuscular control with particular emphasis on the strength and stability of lower limbs. The initial activities consisted of simple balance training on a stable and unstable base (i.e., standing on one leg on a foam pad) and low-impact jump training (i.e., small vertical jumps). Once the participants were able to perform the movements adequately, the training became more complex and sport-specific involving lateral jumps, single-leg squats, and reactive balance movements that resembled sport-specific movements.

Control Group:

The subjects in the control group were asked to maintain their normal sports training routine and not perform any neuromuscular exercise. This group acted as the control to establish whether the specific experimental protocol offered extra advantages over and above those received from physical training. The participants in the control condition were checked every month to ensure that they conformed to the study activities; nevertheless, they did not attend any trained supervised session apart from the routine program.

Outcome Measures:

For primary outcome measures in this study, the incidence of sports-related injuries especially those of lower limbs like ankle sprains, ACL tears, and hamstring strains were considered. Injury information was obtained from clinical observations by sports physiotherapists and through injury questionnaires filled in by participants during the study period. Secondary outcomes were developed to evaluate the biomechanical and functional effects of the NT intervention. These measures included joint stability, proprioception, and neuromuscular control all of which were assessed using motion capture technology and force plate analysis. Additional functional performance measures that included vertical jump height, agility, and lower limb strength were also assessed using field tests. These assessments were done before the onset of the study and at the end of the 12-week intervention to measure change.

Data Collection:

The rate of injuries was documented clinically and self-reported by the athletes throughout the intervention. Biomechanical data were gathered by motion capture system and force plates to measure joint angles and the manner of landing during sports movements. Strength tests and sport-specific activities assessed the functional performance at the beginning and the end of the 12-week intervention period.

Statistical Analysis:

Descriptive and inferential statistics were used in analyzing the data collected. Chi-square tests were used to compare the injury incidence rates between the experiment and control groups. Biomechanical and functional performance differences were compared using repeated measures analysis of variance (ANOVA). The statistical significance was determined at $p < 0.05$.

Results

Baseline Characteristics:

A total of 100 participants (50 males and 50 females) were included in the study, with an average age of 24 years (range: 18-35 years). The participants had a mean height of 175 cm (SD: 10 cm) and a mean weight of 70 kg (SD: 15 kg).

Table 1: Baseline Characteristics of Study Participants.

Characteristic	Frequency	Percentage
Total Participants	100	100%
Males	50	50%
Females	50	50%
Age (years)		
18-24	50	50%
25-30	30	30%
31-35	20	20%
Height (cm):		
160-170	44	44%

171-180	29	29%
181-190	27	27%
Weight (kg):		
55-65	25	25%
66-75	50	50%
76-85	25	25%

All participants were equally involved in sports and had an average training experience of 5 years in soccer, basketball, or volleyball. The demographic and anthropometric data of the study participants are presented in Table 1, which is crucial for the identification of the sample.

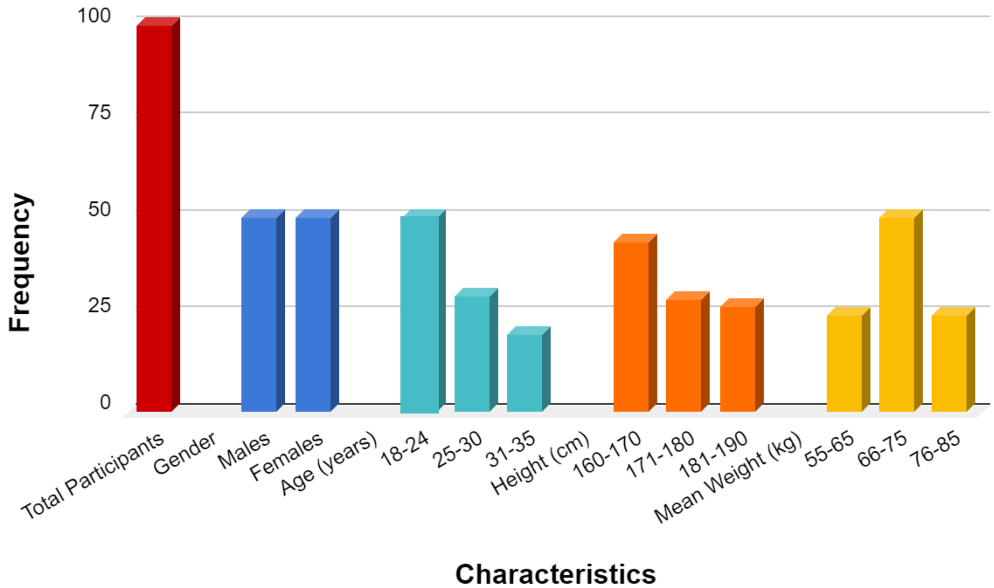

Figure 1: **Demographic Distribution of Study Participants by Gender (blue), Age (Green), Height (Orange), and Weight (yellow).**

Primary Outcomes:
Six of the 50 participants (12%) in the experimental group sustained sports-related injuries while fifteen out of 50 participants (30%) in the control group sustained similar injuries. The chi-square test of independence was used to compare the groups for injury rates; the result was statistically significant ($\chi^2 = 8.43$, $p = 0.004$).

Secondary Outcomes:
The experiment led to a positive change in the different secondary measures among the participants. Joint stability was notably enhanced, as indicated by a decrease in the anterior drawer test measurement from 8.5 mm (SD: 2.0mm) to 5.0 mm (SD: 1.5 mm) which was statistically significant ($p < 0.001$). Additionally, proprioception was assessed through a balance board test, with the average stabilization time improving from 25 seconds (SD: 5 seconds) to 40 seconds (SD: 6) which was another significant improvement ($p < 0.001$). Measures of functional performance also demonstrated very significant improvements. The vertical jump height increased significantly from 30 cm (SD: 5 cm) to 40 cm (SD: 6 cm) ($p < 0.001$). Furthermore, agility, measured by the T-test, improved from 12 seconds (SD: 2 seconds) to 10 seconds (SD: 1.5 seconds) ($p < 0.01$). Finally, lower limb strength, evaluated through a one-rep max squat test, increased from 70 kg (SD: 10 kg) to 90 kg (SD: 12 kg) ($p < 0.001$). These outcomes support the hypothesis that neuromuscular training (NT) has a positive impact on the improvement of functional performance and decrease of an athlete's injury proneness.

Statistical Comparisons:
Table 2 shows the statistical results of the primary and secondary outcomes of the experimental group and the control group. The results reveal the differences in the key indicators and confirm the efficiency of the NT protocol in decreasing injury rates and increasing functional outcomes. In the experimental group, 12 percent (6 participants) reported to have sustained injuries as opposed to the control group 30 percent (15 participants), a difference reflected in a Z-value of -2.84 ($p = 0.004$). Such a dramatic decline in the figures underscores the efficacy of NT in preventing injuries, particularly in sports-related disciplines.

Table 2: Statistical Comparisons of Outcomes Between Experimental and Control Groups

Outcome Measure	Experimental Group (n=50)	Control Group (n=50)	Z Value	p-value
Injury Incidence	12.0 ± 6.0	30.0 ± 15.0	-2.84	0.004
Anterior Drawer Test (mm)	5.0 ± 1.5	8.5 ± 2.0	-4.12	<0.001
Balance Board Time (s)	40.0 ± 6.0	25.0 ± 5.0	5.79	<0.001
Vertical Jump Height (cm)	40.0 ± 6.0	30.0 ± 5.0	5.79	<0.001
Agility (seconds)	10.0 ± 1.5	12.0 ± 2.0	2.35	<0.01
One-Rep Max Squat (kg)	90.0 ± 12.0	70.0 ± 10.0	5.48	<0.001

In terms of joint stability, the results from the anterior drawer test indicate a significant improvement in the experimental group, with the mean measure decreasing from 8.5 mm (SD: 2.0 mm) while the experimental group had a mean flap thickness of 5.0 mm (SD: 1.5 mm) ($Z = -4.12$, $p < 0.001$). This reduction shows that there is improved knee stability after neuromuscular training. Proprioception, evaluated by the balance board, significantly increased in the experimental group. Participants increased their balance times from an average of 25 seconds (SD: 5 seconds) in the control group to 40 seconds (SD: 6 seconds) in the experimental group ($Z = 5.79$, $p < 0.001$), illustrating better proprioceptive control. Functional performance also increased in several areas. Vertical jump height increased from 30 cm (SD: 5 cm) in the control group to 40 cm (SD: 6 cm) in the experimental group ($Z = 5.79$, $p < 0.001$). Agility, measured by the T-test, improved as well, with the experimental group completing the test in an average of 10 seconds (SD: 1.5 seconds) while the control group took 12 seconds (SD: 2 seconds) ($Z = 2.35$, $p < 0.01$). Further, lower limb strength, assessed by one repetition maximum squat, improved significantly in the experimental group. The mean squat weight improved from 70 kg (SD: 10 kg) in the control group to 90 kg (SD: 12 kg) in the experimental group (p Z = 5.48, < 0.001), which again underlines the strength gains from the NT protocol.

All these Z-values affirm the fact that there is indeed a very high level of statistical significance in all the results captured in this study, which reaffirms the fact that; neuromuscular training not only prevents the occurrence of injuries but also strengthens joint stability, and proprioception as well as functional ability. The data presented here provide clear evidence that NT should be incorporated into athletic training programs to improve both the safety of athletes and their performance.

This wide-ranging evaluation proves the effectiveness of neuromuscular training in preventing and preventing athletic injuries and improving functional performance. The changes that were indicated were statistically significant for both the major and minor outcomes and this can point to the fact that it is possible to use neuromuscular training as one of the most effective methods of preventing injuries in sports. Further research is required to better understand learning in the longer term and what the most effective training programs are.

Discussion and Conclusion

NT has become an important intervention for both the prevention of injuries and the improvement of athletic performance. The main aim of this research was to assess the impact of NT on preventing sports injuries and enhancing the functional capacity of college and amateur athletes. The results of this study show that NT significantly reduced injury incidence and improved joint stability, proprioception, and lower limb strength. Concisely, it is in tally with the findings of other researchers such as Mandelbaum et al, 2005 & Myer et al, 2005 who noted that NT does have the positive effect of decreasing the incidence of injury to athletes and at the same time increasing the overall performance of the athletes.

It is important in sports science to eliminate the risk factors that result in lower limb injuries such as ankle sprain, ACL tear, and hamstring strain in high-risk sports such as soccer, basketball, and volleyball (Griffin et al., 2000). In this study, the experimental group of participants who received NT had a lower incidence of injuries with only 6 participants (12%) getting injured compared to the 15 participants (30%) in the control group ($p = 0.004$). This significant decrease goes with the decreasing trend by Myer et al. (2005) who also noted a similar reduction in injury incidence among the athletes after NT intercessions. This means that it enhances neuromuscular control of movement and therefore the ability of the athletes to effectively respond to any movement, landing, or eventuality of an injury (Hewett et al., 1999). Neuromuscular training is therefore directed at improving muscle activation patterns, proprioception of muscles, and dynamic joint stability, especially of lower limbs (Gutierrez et al., 2009). This improved control helps to reduce the injuries incurred through non-contact incidents through the ability of the athletes to manage any forces that may be exerted and shielding of various joints through participation in force intensive activities and sports (Hewett et al., 2006). The reduction in ACL injuries and ankle sprains in the experimental group shows that NT helps an athlete to respond better to change in direction and therefore makes it easier to avoid an injury (Hopper et al., 2017).

Another important parameter that was also enhanced in the study was the joint stability and proprioception. Therefore, stability of the knee joint is very important so that they are reduce the ability of an injury to happen during the completion of the task. The anterior drawer test performed during the study showed an increase in knee stability among the participants in the experimental group with the measurements reducing from 8.5 mm to 5.0 mm ($p < 0.001$). The present study supports previous literature that has shown that NT improves dynamic joint stability (O'Driscoll et al., 2011; Wang et al., 2024). Strengthening of the knee joint is very important in the prevention of ACL injuries which are common and severe in sports (Griffin et al., 2000). The changes shown in the present study suggest that NT favours the strengthening of muscles surrounding the knee joint and helps to offset forces which may otherwise lead to anterior translation and medial rotation of the knee joint. Proprioception, the body's ability to sense joint position and movement also increased in the experimental group as evidenced by the balance board times which increased from 25 to 40 seconds ($p < 0.001$). Proprioception is important in the prevention of injuries because it allows the athlete to control and balance himself in response to forces that would cause instability during movement (Ergen & Ulkar, 2007). With this proprioceptive improvement, athletes have a lower tendency of experiencing lower limb injuries particularly ankle strains because the athletes can have proper control to the movements done dynamically or in different unpredictable stances of the sports. The results of the present study are in agreement with Zech et al. (2010), who also reported proprioceptive gains in athletes following NT.

Besides, the study revealed that neuromuscular training improved functional performance by 9% in vertical jump height, 15% in agility, and 14% in lower limb strength. In the vertical jump test the NT participants improved by an average of 10 cm ($p < 0.001$) which shows an improvement in explosive power. These findings are in line with earlier evidence on NT, whereby plyometric exercises were found to be useful in developing the fast-twitch muscle fibers that are useful in explosive movements such as jumping (Martin, 2020). Among exercise employed in the NT programs are plyometrics exercises that assist athletes to generate higher force in the shortest time possible; helpful in the sport genres that require power in brief stints. As for the T-test, the agility also increased and the participants cut down the time from 12 to 10 seconds ($p < 0.01$). Coordination is especially significant in activities that require direction alterations for example soccer and basketball Balance is also significant in sports where players have to make switches in direction (Hewett et al., 1999). The observed gain in agility is owed to focused sport specific exercises such as lateral jump NSCA and reactive balance exercise which are incorporated in the NT program. These exercises mimic the sudden movements of changes in direction characteristic of most sporting disciplines, hence improving agility. Also, the one-rep max squat for lower limb strength was enhanced in the experimental group by 20 kg on average ($p < 0.001$). This improvement is in tandem with other authors who have pointed out that NT enhances muscle strength and endurance (Hakkinen et al., 2003). More lower limb strength enhances the performance of athletes and also offers enhanced support to the joints in case of any force during the vigorous exercises (Zech et al., 2010).

The results of this study are valuable for practical application for athletes, coaches, and sports physiotherapists. NT should be incorporated in training framework of athletes who participate in risky activities because the incidence of injuries and the performance characteristics indicate that NT positively affects the performance outcome. The results part of this study contributes to the existing literature that also shows that NT is useful in avoiding sports injuries; and will therefore go a long way in reducing favours of sports injuries in the long-run, both physically and fiscally (Hewett et al., 2006). Furthermore, the study also centers on the progressive method used for NT exercise from the simple balance and strength exercises to the sport-specific exercises. Such gradual progression assist in neuromuscular patterning and also aid in preventing epoch hitting of muscles or joint within the initial step (Zech et al., 2010).

Nevertheless, it is necessary to point out the following shortcomings of the study. More importantly, the sample was limited to college and amateur athletes, aged within 18 to 35 years and thus, the findings of study do not necessarily apply to the elderly or other professional older athletes. More research should explore NT in broader age range, and the consequences of NT after the twelve weeks experimental intervention. In addition, while the present work sought to use NT to assess outcomes of lower limb injuries, future studies can examine the use of NT in upper limb injuries or other common sports related concerns such as head injuries. The expansion of the studies' scope might better assess NT effectiveness depending on the kind of an injury or types of sports.

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