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RESEARCH ARTICLE

Effects of Neuromuscular Exercise on Dynamic Balance, Vertical Jump and Trunk Endurance in Ice Hockey Players: A Randomized Controlled Trial

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Abstract

This study aims to investigate the impact of a 12-week neuromuscular exercise program on balance, vertical jump, and core endurance parameters in female ice hockey players. Y balance test, vertical jump test and McGill test were used for evaluation of dynamic balance, vertical jump and trunk endurance, respectively. A 12-week training program was conducted on 50 female ice hockey players. The exercise group showed significant differences in anterior and posteromedial balance scores for both right and left ($p<0.05$), but there was no significant difference in posterolateral scores ($p>0.05$). The control group didn't show significant improvements in the vertical jump ($p>0.05$), while the neuromuscular exercise group demonstrated a statistically significant improvement ($p<0.05$). Trunk extension endurance improved significantly in the control group ($p<0.05$), but there were no significant differences in trunk flexion and lateral endurance ($p>0.05$). In contrast, the neuromuscular exercise group significantly improved all trunk endurance values ($p<0.05$). Neuromuscular exercise training applied to ice hockey players can improve the balance, vertical jump, and trunk endurance parameters. Therefore, the inclusion of neuromuscular exercise programs in the training programs of female ice hockey players can enhance their physical performance and may reduce the risk of injury.

Keywords
Endurance, Exercise, Physiotherapy, Rehabilitation

INTRODUCTION

The initial success of female ice hockey players is an important sign of the tendency toward more equal gender representation. While still the case, one must admit that female players encounter very different problems during the training and competition sessions because of the specifics of their anatomy and biomechanics compared to men (Ransdell & Murray, 2011; Tuominen et al., 2016). Physiological and biomechanical elements, including muscle strength, size, and distribution, as well as hormonal variations, have a considerable influence on the particular requirements of female ice hockey players (Schick & Meeuwisse, 2003). Understanding and addressing these unique challenges are crucial in providing tailored training programs that effectively enhance the performance of female athletes in the sport.

With its quickness, gear, and body combining, ice hockey is high on the list of hazardous sports. One can suffer a great variety of injuries in ice hockey that include concussions, head/ neck traumas, leg and foot injuries, shoulder problems, and muscle strains (Mosenthal, Kim, Holzshu, Hanypsiak, & Athiviraham, 2017; Wörner, Kauppinen, & Eek, 2024). These injuries can result in significant short- and long-term health effects for players, including cognitive, psychological, and physiological consequences. As a result, it is crucial to design training programs that address the specific needs of female athletes to

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optimize their performance and reduce the risk of injuries. The focus of an exercise program for ice hockey players depends on the season stage. In-season training aims to maintain the strength and movement patterns developed during the off-season while preparing players for the demands of training camps and regular-season play (Allard, Martinez, Deguire, & Tremblay, 2022). Research has shown that off-ice physical performance correlates with on-ice performance in elite ice hockey players. Various off-ice variables such as strength, agility, and fitness have been found to correlate with on-ice-skating sprint performance and overall game performance. These findings suggest that off-ice exercise and physical performance are important factors in determining the on-ice performance of ice hockey players (Farlinger, Kruisselbrink, & Fowles, 2007; Schwesig, Laudner, Delank, Brill, & Schulze, 2021; Wagner et al., 2021; Williams, 2020).

Female ice hockey athletes must focus on polishing their balancing skills, jumping abilities, and endurance if they want to become elite players. They are the skills that can give a substantial performance on the ice. Developing these skills requires a multifaceted approach that includes targeted exercises and training regimens Numerous exercise strategies target improving performance and minimizing injury risk for ice hockey athletes (Dæhlin et al., 2017; Hedrick, 2002; Wolfinger & Davenport, 2016). Athletic performance, injury prevention, and physical fitness are among the many beneficial areas identified in neuromuscular training studies which is of great interest for the field of sports physiology and exercise physiology. What we term neuromuscular training is a particular type of training that focuses on optimizing the coordination of actions of the nervous system and the muscles. While it uses a mixture of strength, balance, coordination, and proprioceptive exercises, it enables individuals to have more control over their body and efficient movement. Neuromuscular training aims to optimize muscle activation, joint stability, and overall neuromuscular control, leading to improved athletic performance and reduced risk of injuries (Akbar et al., 2022; Zouhal et al., 2019; Sarıca & Gencer, 2024).

Neuromuscular exercise training emphasizes the motor neuron functioning to coordinate the muscles well, ultimately leading to the refinement of coordination, balance, and general movement. This training regimen, with great success in many sports for maximizing performance and injury prevention, is widely used. However, its application to female ice hockey players has not been extensively studied. With the specific goals of improving balance, jumping, and endurance in this population, we must first understand the potential effects of a neuromuscular exercise training program to develop evidence-based interventions. Specific neuromuscular training programs can consider the distinct physical challenges of female ice hockey players. These programs often incorporate exercises that target the lower body, core stability, and proprioception to improve muscle strength, control, and coordination. By enhancing these aspects, players can better withstand the forces exerted on their bodies during the dynamic and physically demanding nature of ice hockey.

The current study sought to investigate the consequences of implementing neuromuscular exercise programs in conjunction with standard training routines on the dynamic balance, vertical jump, and trunk endurance parameters of female hockey players.

MATERIALS AND METHODS

Participants and Recruitment

Female ice hockey players aged between 15 and 30, who are licensed by the Turkish Ice Hockey Federation and actively participating in the league, voluntarily took part in this study. The research was conducted during the season. To be considered for the study, participants were required to be in good health, free from any diseases, and absent any musculoskeletal injuries that would impede their training or affect the measurement outcomes. Additionally, they had to be active club ice hockey players.

In our study, we implemented a randomized controlled trial. Ice hockey players were split into two groups: the neuromuscular training group (experimental) and the control group. The division was done randomly using a computer program. The experimental group underwent 12 weeks of hockey and neuromuscular training while the control group stuck to their regular hockey routine. Assessments were regularly conducted during training sessions throughout the season with tests administered an hour before warm-up.

Study participants were thoroughly informed about the risks, obligations, and advantages associated with the research before they provided written consent. The research project was carried out following the guidelines established by the Declaration of Helsinki, and it was previously approved by the ethics committee at Uskudar University (approval number (61351342/February 2023-16)). Additionally, the study was registered on the ClinicalTrials.gov platform (registration number is NCT05998057).

Procedures

All participants in the study, in addition to providing personal information, were required to complete a demographic form that included details such as their positions, national team history, the number of years they have been involved in sports, their current injury status, any previous surgeries they have undergone, and their regular medication use. The study utilized three tests to evaluate the athletes' balance, vertical jump, and trunk endurance. The Y-Balance Test was used to assess balance, the Vertical Jump Test was used to measure vertical jump, and the McGill Trunk Endurance Test (MGDT) was used to evaluate trunk endurance. These evaluations were conducted twice, at the beginning of the study and again after the 12-week program.

Dynamic Balance Assessment

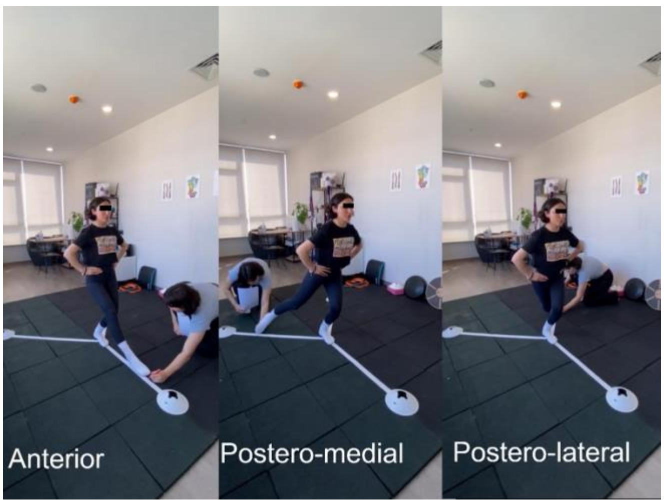

Figure 1. Y-balance test

Y balance test was used to determine the dynamic balance of all athletes. The Y Balance Test (YBT) is a dynamic test used to measure balance, strength, flexibility, core control, and proprioception required for single-leg stance. It is commonly used to assess physical performance, functional symmetry, and the risk of lower extremity injury. The test involves reaching in three different directions: anterior, posterolateral, and posteromedial while standing on one leg (Fig. 1). To score the test, the average reach distance in each direction is calculated, and the distance in each direction is expressed as a percentage of the patient's leg length. The YBT is a reliable tool for assessing balance and identifying athletes at increased risk for injury, making it a valuable test in sports injury prevention and rehabilitation (Plisky et al., 2009; Plisky, Rauh, Kaminski, & Underwood, 2006; Shaffer et al., 2013).

Vertical jump assessment

Vertical Jump Test was used to evaluate the jumping performance of the participants. The vertical jump test, also known as the Sargent Jump, is a test designed to measure lower body strength and power (Sargent, 1921). The test involves measuring the height an individual can jump using a vertical jump test gauge or a marked wall (Fig. 2). The procedure for the vertical jump test is as follows: The person stands sideways against a wall and extends the hand closest to the wall. With the feet flat on the ground, the point of the toes is marked or recorded. This is called standing reaching. The person puts chalk on their fingertips to mark the wall with the height of their jump. The person then moves away from the wall and jumps vertically as high as possible, using both their arms and legs to help propel their body upwards. Try to touch the wall at the highest point of the jump. The distance difference between the standing height and the jumping height is points. The best of three attempts is recorded, and the results can be compared to normative data for various age groups and genders (Maulder & Cronin, 2005).

Figure 2. Vertical jump test, initial position (A), vertical jump (B)

Trunk Endurance Assessment

The McGill Trunk Endurance test is a test that is based on how long a person can maintain a static position as a maximum time (Fig. 3). The different ways to check people's trunk endurance are through the trunk flexor endurance test, trunk lateral endurance test, and trunk extensor endurance test. These tests measure the stability of the deep core muscles, the anterior muscles group, and the lateral core muscles. In this test, the trunk endurance time measured is in seconds, and the test is terminated as soon as the individual notices any changes in trunk position, or exhibits fatigue and can no longer hold the given position. Clinicians mostly rely on the trunk endurance test to monitor the muscle's performance improvement in the context of a rehabilitation program (Evans et al., 2007; McGill et al., 1999).

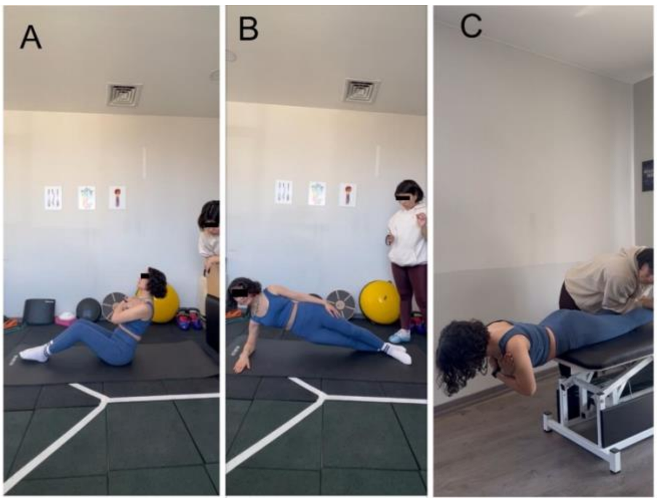

Figure 3. Trunk endurance, flexion (A), lateral (B), extension (C)

Intervention

Routine Training Program

Participants in the control group maintained their conventional training regimen, which consisted of 5 days a week of classical training for 12 weeks. This program comprised a 10-minute warm-up, and 40 minutes of technical and tactical off-ice training, and concluded with a 10-minute cool-down session.

Neuromuscular Training Program

The neuromuscular training program was designed for ice hockey players and includes core stabilization, balance, and plyometric exercises (Table 1). In addition to the routine training programs, athletes in the experimental group underwent supervised neuromuscular training for 40 minutes daily five days a week for 12 weeks. Since our neuromuscular training program includes warm-up exercises, no additional warm-up time is allocated.

Statistical Analysis

The study's sample size was determined by conduc ting a power analysis using G*Power (Version 3.1.9.6 (Faul et al., 2009). The data from the study was analyzed using the licensed SPSS 25 software program. The normal distribution of the variables was examined using the Kolmogorov-Smirnov normality test, and the differences between groups were analyzed using a Dependent Sample T-test due to the normal distribution of the variables. A significance level of $p<0.05$ was accepted when interpreting the results.

RESULTS

Demographics

A total of 50 female ice hockey players participated in a 12-week training program, which included both an exercise group and a control group. The average age of the players in the exercise group was 20.04± 4.06 years, while the average age of the players in the control group was 20.12± 3.90 years. There was no statistically significant difference between the two groups terms of their baseline values ($p>0.05$). Of the 50 participants, 16 were left-dominant and 34 were right-dominant. No significant differences were observed between the groups in terms of the dominant side. The demographic data for the participants are provided in Table 2.

Dynamic Balance

Following the findings of the Y balance test, a substantial rise in values was observed for both the right and left sides in all groups ($p<0.05$). The scores differed significantly between the two groups in the anterior and posteromedial directions for both the right and left sides ($p<0.05$). There was no significant difference in the posterolateral scores between the groups on either the right or left sides ($p>0.05$). A comprehensive presentation of all Y balance scores and their corresponding significance levels can be found in Table 3.

Vertical Jump

Upon analyzing the vertical jump assessment data, it was found that the group that received routine training showed no significant change in their post-intervention values ($p>0.05$). In the neuromuscular exercise group, a statistically significant difference was observed in the post-treatment values ($p<0.05$). There was also a significant difference when looking at the scores between the groups ($p<0.05$). A complete overview of all vertical jump scores and the corresponding levels of significance can be found in Table 3.

Trunk Endurance

In the routine exercise group, the outcome of the post-treatment examination revealed a statistically significant improvement in the trunk extension endurance value ($p<0.05$). There was no significant difference in trunk flexion, and right and left lateral endurance scores ($p>0.05$). In the neuromuscular exercise group, there was a statistically significant improvement in all trunk endurance values ($p<0.05$). An extensive summary of all trunk endurance scores and their corresponding levels of statistical significance can be found in Table 3.

Table 1. Neuromuscular training program

Exercise	Repetition/Duration
Lunge to Hamstrings Stretch	3 sets 30seconds
Standing Hip Out	3 sets 30seconds
90-90 Hip Stretch	3 sets 30seconds
World's Greatest Stretch	3 sets 30seconds
Star Excursion	3 set 5 reps
Side Jumps+ Balance	3 sets 10 reps
Forward Hops + Balance	3 sets 10 reps
Squat	3 sets 10 reps
Squat Jump	3 sets 10 reps
Jumping Spider Push-up	3 sets 10 reps
Double Leg Vertical Jump	3 sets 10 reps
Broad Jumps	3 sets 10 reps
Lateral Box Shuffles	3 sets 10 reps
Plank	3 sets 30 seconds
Side Plank	3 sets 30 seconds
Bird Dog	3 sets 10 reps
Glute Bridge	3 sets 10 reps
Single Leg Glute Bridge	3 sets 10 reps
Single Toe Raises	3 sets 30 seconds
Nordic Hamstrings	3 sets 10 reps
Monster Walk	3 sets 10 reps

Table 2. Demographic data of participants

Data	Group	Values				p
		Minimum	Maximum	Mean	±Sd	
Age (years)	NMT	16,00	28,00	20,04	4,06	0,944
	RT	16,00	28,00	20,12	3,90	
Height(m)	NMT	1,55	1,77	1,65	0,06	0,978
	RT	1,55	1,73	1,65	0,04	
Weight(kg)	NMT	50,00	62,00	55,80	3,98	0,209
	RT	48,00	65,00	57,28	4,24	
BMI (kg/m2)	NMT	17,76	22,23	20,47	1,31	0,169
	RT	18,04	23,88	21,01	1,39	

*NMT: neuromuscular training; kg: kilogram; m: meter; RT: routine training sd: standard deviation; p: statistical significance

Table 3. Balance, vertical jump and endurance scores

Data	Group	Values			
		Pre mean±sd	Post mean±Sd	p0	p1
Y-balance anterior right(cm)	NMT	95±2,48	99,54±2,76	<0.001	
	RT	95,20±2,69	97,65±2,39	<0.001	0,005
Y-balance anterior left(cm)	NMT	94±2,45	99±2,68	<0.001	
	RT	94,68±3,22	97,1±2,6	<0.001	0,001
Y-balance posteromedial right(cm)	NMT	81,43±2,47	83,98±2,1	<0.001	
	RT	79,9±2,41	81,45±1,99	<0.001	0,024
Y-balance posteromedial left(cm)	NMT	80,74±1,87	82,89±1,72	<0.001	
	RT	79,76±1,9	80,61±1,74	0.008	0,009
Y-balance posterolateral right(cm)	NMT	77,96±2,53	80,83±1,94	<0.001	
	RT	75,97±2,32	78,06±2,36	<0.001	0,09
Y-balance posterolateral left(cm)	NMT	77,37±2,12	79,94±1,51	<0.001	
	RT	75,42±2,35	77,86±2,1	<0.001	0,806
Vertical jump(cm)	NMT	16,52± 1,26	16,32±1,07	<0.001	
	RT	17,56±1,04	16,48± 1,08	0,212	0,001
Trunk flexion endurance(sec)	NMT	72,56±2,79	76,00±1,66	<0.001	
	RT	71,28±2,26	71,28±2,26	-	<0.001
Trunk right lateral flexion endurance(sec)	NMT	47,16±2,08	49,00±1,83	0.006	
	RT	46,96 ±1,95	47,04 ±1,97	0.161	0,006
Trunk left lateral flexion endurance(sec)	NMT	46,64±2,98	48,52±1,85	0.003	
	RT	46,92±3,12	47,36±2,83	0.102	0,025
Trunk extension endurance(sec)	NMT	68,68±2,04	76,32±1,68	<0.001	
	RT	69,24±2,55	70,56±2,52	<0.00	<0.001

*p0: within-group statistical significance p1: between-group statistical significance

DISCUSSION

While previous studies have demonstrated the positive impact of neuromuscular training programs on various aspects of athletic performance in different sports, the current study delved deeper into understanding the unique requirements of female ice hockey players. This approach aimed to provide valuable insights tailored specifically to address the complex and distinctive needs of this athletic population. Our study's findings indicate that the neuromuscular exercise program is effective in enhancing balance, vertical jump, and trunk stabilization in female ice hockey athletes. Furthermore, our research is the first to investigate the impact of such a program on these specific aspects.

The influence of neuromuscular training on athletic performance has been extensively examined in numerous studies, which have consistently revealed its beneficial effects on various aspects of physical fitness. Neuromuscular training has been shown to improve dynamic balance, and sports performance, including sprint, agility, and power abilities in female basketball players (Hewett et al., 2005). It also reduced the incidence of serious lower limb injuries and improved lower limb strength and postural control (Filipa et al., 2010). Plyometric and dynamic stabilization and balance training have been effective in increasing measures of neuromuscular power and control, suggesting that a combination of these training types may maximize preseason training effectiveness for female athletes (Pasanen et al., 2009). Systematic reviews have indicated that neuromuscular training can decrease injury incidence and that a combination of plyometric power, biomechanics and technique, strength, balance, and core stability training can induce neuromuscular changes and potential injury prevention effects in female athletes (Myer et al., 2005). Neuromuscular training programs focusing on core stability and lower extremity strength have improved performance on the star excursion balance test in young female athletes (Myer et al., 2006). Comprehensive neuromuscular training programs have been associated with improved performance measures and lower-extremity movement biomechanics related to ACL injury risk (Benis et al., 2016). Body-weight neuromuscular training has been shown to improve postural control and lower limb stability in female basketball players, as assessed with the Y-Balance Test (Kim et al., 2017).

Neuromuscular training programs have been shown to improve vertical jump performance in female collegiate athletes, with significant increases in initial and maximum knee flexion angles during drop jumps, and improved performance in vertical jump and hopping tests (Pasanen et al., 2009). Neuromuscular training has also been effective in reducing lower limb injury incidence and improving physical fitness measures such as countermovement jump performance and balance in young female track-and-field athletes (Kooroshfard & Rahimi, 2022). Plyometric training was found to have positive effects on vertical jump in young basketball athletes, with significant improvements observed in countermovement jump and squat jump (Correia et al., 2020). A study revealed that a neuromuscular warm-up program led to enhanced jumping performance and static balance in floorball players (Bonato et al., 2018). A six-week neuromuscular training program resulted in improved athletic performance measures and altered movement patterns during jumping tasks in female collegiate athletes (Chappell & Limpisvasti, 2008). A systemic review and meta-analysis state that combined strength training, which includes plyometric and traditional strength exercises, has a moderate effect in improving vertical jump performance in basketball players (Uysal et al., 2023). After an 8-week neuromuscular warm-up program, elite junior skiers demonstrated improved dynamic balance ability; however, no statistically significant changes were observed in vertical jump performance (Vitale et al., 2018).

Trunk endurance is a key aspect for athletes as it contributes to overall core stability and function. Trunk endurance refers to the ability of the trunk muscles to sustain contractions over some time. Studies have found that trunk muscle endurance significantly increased following exercise training (Song et al., 2023; Taneja et al., 2023). Although trunk endurance is an essential aspect for athletes, research on the development of this parameter, particularly in ice hockey players, is limited.

Our study demonstrates that dynamic balance, vertical jump, and trunk endurance can be enhanced through the implementation of neuromuscular exercise training in conjunction with routine programs. Moreover, the study may pave the way for further research exploring the long-term effects of neuromuscular exercise training on injury prevention and overall performance in female ice hockey. Longitudinal studies tracking the participants beyond the 12-week intervention period can provide insights into the sustainability of the observed improvements and the potential reduction in injury incidence. Additionally, investigating the underlying physiological mechanisms, such as neuromuscular adaptations and motor control changes, through advanced techniques like electromyography and motion analysis, can deepen our understanding of how neuromuscular exercise training influences the physical attributes of female ice hockey players.

In conclusion

The findings of this randomized controlled trial underscore the potential of a 12-week neuromuscular exercise training program to improve balance, jumping ability, and endurance in female ice hockey players. Drawing upon recent literature, this study highlights the multifaceted benefits of neuromuscular interventions for enhancing athletic performance, reducing injury risk, and optimizing player development in ice hockey and beyond. Future research endeavors should focus on elucidating the long-term effects, optimal implementation strategies, and scalability of such interventions to maximize their impact on female athletes' health and performance outcomes.

Conflict of interest

The authors declare no conflict of interest. Also, no financial support was received.

Ethics Committee

The approval was taken from the Üsküdar University Non-Interventional Research Ethics Committee (reference number 61351342/February 2023-16).

Author Contributions

The authors accomplished this study by making significant contributions including designing the study according to the formulation of its objectives.

MK and ÖŞ performed on conception and design of the study. MK collected the data. ÖŞ and ES performed data analysis and interpretation. All authors were contributors and responsible for the manuscript's content and approved the version submitted for publication.

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