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Does the "prevent injury and enhance performance program" improve the performance in female handball teams?

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Abstract. *Aim*. The purpose of this study was to investigate the effects of adding "Prevent Injury and Enhance Performance Program (PEP)" on jump performance, flexibility, agility, muscle strength, and balance in professional female handball players. *Material and Method*. 64 players (age 26.2±4.9 years) were randomly assigned to a PEP (n=32) or a control group (n=32). Both groups performed their regular training program where the PEP group additionally performed PEP training 3 times per week for 20 weeks. Teams were assessed at baseline and after 20 weeks by using the Sit and Reach Test, hand-held dynamometer, Star Excursion Balance Test, Illinois Agility Test, Single Leg Hop Test, Triple Leg Hop Test. *Results*. Both groups showed similar improvements in all tests ($p < 0.05$), except for the Star Excursion Balance Test test. Star Excursion Balance Test scores in anterior and anteromedial directions were significantly higher in the PEP group. *Conclusion.* In conclusion, the Prevent Injury and Enhance Performance Program, added to routine training in the professional female handball players, has positive effects on dynamic balance but had no effect on agility, flexibility, muscle strength, functional jumping performance.
Key words: *athlete, injury prevention, neuromuscular training, performance*.

Introduction

Handball competitions require advanced physical performance such as jumping, running and explosive shooting skills (1). During a handball match, more than 825 high intensity actions can be performed, requiring a high level of strength (2). In 1999, a team of experts gathered by Santa Monica Orthopaedic and Sports Medicine Research Foundation developed the PEP program in order to implement a specific training program to prevent injuries incurred by female soccer players. The program's main focus is educating players on strategies to avoid injury and includes specific exercises targeting problems such as biomechanics, strength deficits and coordination of the stabilizing muscles around the knee joint. This prevention program consists of a warm-up, stretching, strengthening, plyometrics, and sport-specific agility drills. Extensive neuromuscular training programs that include plyometrics, core strengthening, balance, resistance or speed/agility training may improve several measures of performance attendance and the while enhance biomechanical standards related to lower extremity injury risk (3-6). Hence, handball coaches should perform specific exercises to develop these physical qualities and prevent injuries. However, compliance with programs is a source of concern (7) and it may be difficult to motivate coaches and players to follow up with such exercise programs to prevent injuries only unless they benefit directly from the performance. Based on this view, studies were conducted to examine the effect of injury prevention programs on performance. Until now, there is no sufficient information about the impact of different prevention programs on physical performance. Therefore, the aim of this study was to investigate the effects of the PEP training program on flexibility, agility, strength, and balance in professional female handball players.

Material and Method

Study design and recruitment. 64 athletes from four teams of the Turkish Women Handball Super League participated in the study. These teams, selected from among fourteen teams, were the four most successful teams in the league in the previous season and their performance levels were close to each other. Randomized teams were divided into two groups. Two teams (n = 32) formed the control group and two teams (n = 32) formed the intervention group (PEP group)(Figure 1). In the study, voluntariness was taken into consideration for the participation of the athletes and the necessary permits were obtained from the team

responsible. Athletes with acute injuries were not included in the study. The study was approved by the Ethics Committee of the Faculty of Medicine in Pamukkale University.

Intervention. Both groups were instructed to perform their regular training program, and the PEP group additionally performed PEP training 3 times per week for 20 weeks starting from the preparation period until the end of the first season. The PEP program was explained to the athletes and coaches before and during the preparation season.

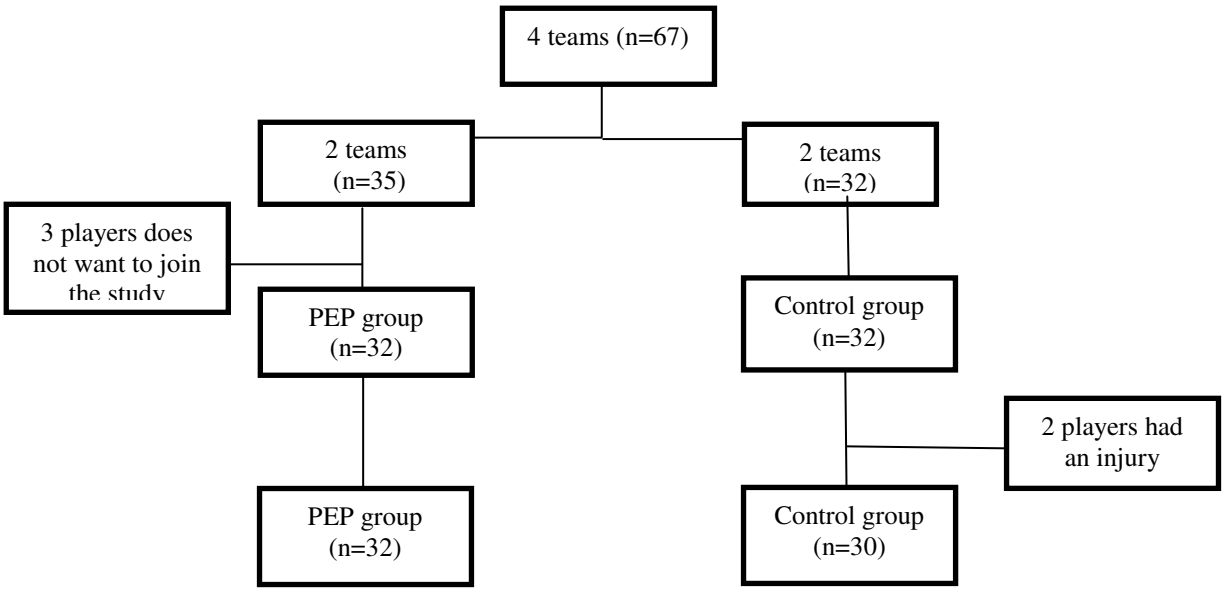

Figure 1. Flow chart

The team coaches were instructed to perform the program at least 3 times a week. The content of PEP training is given in table I. In the training session of the PEP program, how to do the exercises with the appropriate biomechanical technique was explained to the coaches and athletes. The duration and distance information of the exercises were explained in detail. PEP exercises consist of 3 basic warm-up exercises, 5 stretching techniques for the trunk and lower extremities, 3 strength exercises, 5 plyometric activities, and 3 specific exercises. No intervention was given to the control groups other than their regular training.

Table I. PEP training program

Warm-up	Strengthening	Plyometric	Agility	Stretching
Jog (cone to cone)	Walking lunges	Lateral hops over a cone	Shuttle run with forward/backward running	Calf stretch
Shuttle run (side to side)	Russian hamstring	Forward/backward hops over a cone	Diagonal runs	Quadriceps stretch
Backward running	Single toe-raises	Single leg hops over a cone	Bounding run	Hamstring stretch
		Vertical jumps with headers		Inner thigh stretch
		Scissors jump		Hip flexor stretch

Age, height and body weights of the participants were recorded. In addition, demographic information and injury history were collected by face-to-face interview method (Table II). The athletes were asked to keep a daily injury log. Performance tests were performed at the beginning and after 20 weeks. The tests were carried out at the same training field where each team has been training. The tests were performed by the same physiotherapist.

Illinois agility test. Three cones were placed on a straight line The athletes were tested in the test track consisting of three cones, which were arranged on a straight line with a width of 5 m, length 10 m and a distance of 3,3 m in the middle section. The test was explained to the athletes before the testing session.
Then, they were allowed to perform standard warm-up exercises including runs and dynamics stretching. The stopwatch was started at the start of the test and stopped as soon as the athlete reached the finish line. After 5 minutes of rest, the test was repeated and the best result was recorded (8-9).
Single leg hop test. A line was drawn on the ground and the athletes were asked to place their toes behind the line. Then, they were asked to jump as far as possible with a single leg. A marker was put on the front of the toes and the distance between the marker and the line was recorded in centimeters. The test was repeated three times and the best result was used for the analysis (10-11).
Single Leg Triple Jump Test. A line was drawn on the ground and the athletes were asked to place their toes behind the line. Then, they were asked to make consecutive 3 single leg jumps and go to the furthest point. A marker was put on the front of the toes and the distance between the marker and the line was recorded in centimeters. The test was repeated three times and the best result was included in the study (11).
Sit and reach test. This is a standard test used for flexibility assessment. To begin this test, the athlete sat on the floor with both legs straight and feet behind the box. The athlete was then asked to do forward flexion as far as possible over the body of the trunk (waist and hips) without flexing the knees. The farthest reaching point of the fingers was measured in centimeters. This test was repeated 3 times and the best result was recorded (12).
Knee Extensor Muscle Strength Measurement. Knee extensor muscle strength of the athletes was evaluated with a Hand Held Dynamometer and recorded in Newtons (N). The instrument was calibrated and the values of the previous measurement on the LCD display was reset before each use. The maximal voluntary isometric contraction, which was reported to be reliable in the literature, was used for muscle strength measurements. The make test is the maximum force-to-measure protocol of the person measuring the device while keeping the metering dynamometer constant (13-14-15). Measurements were repeated twice for lower extremities at 30-sec intervals and the measurements were averaged (16). The athlete's feet on a chair that will not come into contact with the ground, the hips and knees are 90º flexed, feet free, arms crossed on the chest and the support was placed in such a way. The athletes were informed about the test protocol before starting the test. A towel was placed under the knee joint to be evaluated. An extension was determined until the knee was locked, and the dynamometer was placed 1-2 cm above the level of the malleolus.
Star Excursion Balance Test. The balance was used for performance evaluation. The athletes stopped at the center of an 8-line star-like device drawn at 45º angles and were asked to extend to the anterior, anteromedial, medial, posteromedial, posterior, posterolateral, lateral and anterolateral directions using one of their feet. Athletes have touched the farthest point where they can reach with the most extreme part of the elongation leg and the mean of the results is recorded in centimeters by making three attempts in each direction (17).
Statistical analysis. The data were analyzed with the SPSS 22 package program. Continuous variables are given as mean ± standard deviation and categorical variables as number and percentage. In-group comparisons of pre- and post-exercise comparisons of t-test independent groups when parametric test assumptions are provided; Wilcoxon test was used when the parametric test assumptions were not provided. Since the difference values did not have a normal distribution, the groups were compared by using the Mann-Whitney U test. For statistical significance, $p < 0.05$ was accepted.

Results

Initially, 64 athletes participated in the study. Both groups were composed of 32 athletes. However, in the control group, two athletes were excluded from the study because of anterior cruciate ligament (ACL) injury. PEP group 32, control group 30, a total of 62 athletes were completed. No significant difference was found between the groups in terms of age, height, weight, and handball play time when the demographic data of the groups were compared (Table II) ($p > 0.05$).
Sit & Reach Test. In both groups, a significant difference was found when the values in the pre and post education were compared (PEP group $p=0.001$; Control group $p=0.006$). There was no significant difference between the groups after training for the Sit and Reach Test (Table III) ($p=0.082$). *Illinois Agility Test.* When the values of the groups before and after the training were compared, a significant difference was found ($p=0.000$). However, there was no significant difference between the test and the differences between the groups after the training ($p=0.816$).

Knee Extensor Muscle Strength Measurement. In both groups, there was a significant difference when the values of the right and right legs were compared before and after the training (p=0.000). There was no significant difference between the groups in the right and left legs after the training (p=0.635 for the right leg, p=0.784 for the left leg) (Table III).

Star Excursion Balance Test. In the PEP group, significant improvement was observed in all directions except right leg posterior, postero-lateral and left leg posterior. In the control group, there was no significant difference in all aspects before and after the training. When the groups are compared in terms of difference values, the right leg in favor of the PEP group anterior (p= 0.008), and there is a difference in favor of the left leg anterior (p=0.002), antero-medial (p=0.056) directions (Table III).

Single Leg Hop Test. In both groups, there was a significant difference when compared to the values of the right and left legs before and after the training (p=0.000). There was no significant difference between the groups in the right and left legs after the training (p=0.129 for the right leg and p=0.459 for the left leg) (Table III)

Triple Leg Hop Test. In both groups, there was an increase in meaning when compared to the values in the right and right legs before and after the training (p=0.000). There was no significant difference between the groups in the right and left legs after the training (p=0.341 for the right leg and p=0.961for the left leg) (Table III).

Table II. Demographic data of participants

	PEP group (n=32)	Control group (n=32)	*p*
	X ± DS	X ± DS	
Age (year)	25.31 ± 5.06	27.03 ±4.97	0.17
Height (cm)	172,34 ±4.77	173,43 ±4.93	0.38
Weight (kg)	66.81 ± 5.08	67.8 ±6.61	0.511
Time played handball (year)	13.28 ± 4.44	14.87 ±4.36	0.161

Values are mean ± SD. P -values from independent t-tests. PEP, Prevent Injury Enhance Performance.

Table III. Results from posttest (mean ± 95% CI) within the PEP and Control groups

	PEP group (n=32)	Control Group (n=30)	*p*
	X ± SS	X ± SS	
Sit and reach test	32.1 ± 2.16	32.96 ±1.6	0.082
Illinois agility test	19.3 ± 2.0	19.5 ± 2.1	0.816
Knee Extensor Muscle Strength (right leg)	233.03 ± 11.32	231.77 ± 9.41	0.635
Knee Extensor Muscle Strength (left leg)	236.5 ± 11.93	235.73 ± 9.81	0.784
Single leg hop test (right leg)	180.8 ± 12.2	185.5 ± 11.4	0.129
Single leg hop test (left leg)	185.3± 14.6	188.7 ± 12.6	0.459
Triple leg hop test (right leg)	562.2 ± 32.7	570.1 ± 28.3	0.341
Triple leg hop test (left leg)	575.6 ± 31.5	577.3 ± 27.8	0.961
SEBT rigth leg A	94.66 ± 5.88	89.97 ± 7.44	**0.008**
SEBT rigth leg AM	90.16 ± 9.3	92.93 ± 9.97	0.142
SEBT rigth leg M	93.66 ± 9.32	95.83 ± 7.27	0.312
SEBT rigth leg PM	96.66 ± 13.44	99.3 ± 12.36	0.310
SEBT rigth leg P	86.88 ± 6.81	89.3 ± 7.47	0.366
SEBT rigth leg PL	92.34 ± 9.7	94.07 ± 6.53	0.582
SEBT rigth leg L	86.47 ± 7.02	87.07 ± 5.84	0.718
SEBT rigth leg AL	86.38 ± 6.09	83.3 ± 7.53	0.073
SEBT left leg A	95.63 ± 4.8	90.83 ± 6.49	**0.002**
SEBT left leg AM	97.19 ± 6.54	94.23 ± 7.35	**0.056**
SEBT left leg M	97.28 ± 8.03	96.7 ± 7.75	0.773
SEBT left leg PM	102.41 ± 10.75	102.1 ± 11.05	0.938
SEBT left leg P	90.63 ± 10.48	90.77 ± 6.77	0.950
SEBT left leg PL	95.91 ± 11.5	92.87 ± 8.32	0.113
SEBT left leg L	90.94 ± 5.75	89.93 ± 8.46	0.475
SEBT left leg AL	84.72 ± 5	82.37 ± 5.32	0.078

SEBT: Star Excursion Balance Test. A: Anterior, AM: Anteromedial, M: Medial, PM: Posteromedial, P: Posterior, PL: Posterolateral, L: Lateral, AL: Anterolateral. Values are mean ± SD. PEP, Prevent Injury Enhance Performance.

Discussion

In our study, the PEP Program was applied to 32 Turkish Women Handball Super League players in addition to the routine training program 3 times a week for 20 weeks. The results obtained from the study showed that the PEP training program added to the routine training program positively affects the dynamic balance in the professional handball players, but it has no effect on flexibility, agility, muscle strength and functional jump. Upon a review of the literature, no study examining the effect of PEP training on performance of professional women handball players has been found. However, in a study examining the effect of a different prevention program on performance in female handball players. Myklebust et al (7). applied a prevention program for women's Norwegian Handball Federation teams, which were prepared specifically for handball during three seasons. The program focuses on improving the athlete's awareness of movement while controlling knee balance during standing, cutting, jumping, and landing. In the evaluation before the relevant season and after three seasons, the prevention program decreased the ACL injuries, but no statistically significant difference was found between the tests that control the knee balance during standing, cutting, jumping and landing. In another study, the effect of the FIFA 11 warm-up program on the performance of adolescent footballers was investigated. Steffen et al (18) divided 34 adolescent girls, aged between 16 and 18 years, into an intervention group (n = 18) and a control group (n = 16) and examined the effect of an injury prevention program for 10 weeks on performance. In this study, the FIFA 11 warm-up program, formed by F-MARC (2005) consisting of 15 minutes, 10 different exercises, core stabilization, neuromuscular training, eccentric hamstring strengthening, and agility exercises was applied to the intervention group. In the study muscle strength quadriceps, hamstring, hip abductor, adductor concentric, eccentric and isometric tests, splash performance Counter Movement Splash test, Vertical Drop Jump test, and Rebound Splash test, sprint assessment football-specific tests were used. As a result of the study, they explained that the prevention program has minimal effect on performance in female adolescent football players. They explained the reason for this was that their exercise level in the prevention program was too low to provide improvements in performance. In our study, after 20 weeks of the training program, athletes developed muscle strength, jumping performance, flexibility, and agility, but a similar improvement was observed in the control group as well. Steffen et al (18) pointed out the necessity of increasing the amount of stimulus to increase physical performance by focusing on reducing the landing forces after the jump with plyometric exercises. In the literature, studies examining the effect of PEP on performance in different sports branches were found. The effect of the PEP program on the performance of female adolescents playing football was evaluated (19-20) As a result of the study, which was attended by 58 girls, a decrease in their sprint and agility, and an increase in their jump rate was observed in both groups who received and did not receive the PEP training. The authors emphasized that the blocking program had minimal impact on performance and the programs to be organized should be more detailed and improved (20). Another study examining the effect of the PEP program on performance was the participation of 20 female football players with an average age of 18.6 ± 2.7 years. In the study, dynamic valgus arrays were measured by video analysis while maximal quadriceps, hamstring and gastrocnemius forces were measured by dynamometer during the vertical jump of the participants. As a result of a 24-week long-term study without a control group, quadriceps and hamstring muscle strength increased significantly in the right lower extremity ($p < 0.001$)(19). To date, very few studies have examined the impact of the ACL injury prevention program on agility performance. Our results showed that the PEP program did not improve the agility performance of the Illinois Test (21) emphasized that the test applied to training and testing for agility performance should be highly suitable to the relevant branch of the sport. In their study, they examined the athletes' ability to transfer linear sprint training to agility performance. The results of this study provided some supportive evidence for the possible reasons that drills in the PEP program are unable to provide an increase in agility performance. The agility drills in the PEP program require small angles (<90°) during changing direction or reciprocating transitions. In contrast, the two agility tests used in the current study include sharp direction changes that can be extremely challenging compared to the demands of the intervention. In our study, it was observed that PEP training did not affect the strength, flexibility, jumping and agility performance but positively affected the dynamic balance. The Star Excursion Balance Test (SEBT) is a dynamic test that requires strength, flexibility, and proprioception, and is used to assess physical performance. We used the SEBT test in our study because it is a reliable test that evaluates dynamic stability in multiple planes (22). Studies conducted to date have not examined the relationship between lower extremity performance and SEBT. In previous studies, however, the relationship between SEBT and lower extremity injury risk was

described (23). Plisky et al. reported that asymmetry between the feet at the anterior extension, as well as the sum of three directions (anterior, posteromedial and posterolateral), predicted lower extremity damage in high school basketball players. The results obtained from our study showed that the PEP training program added to the routine training program positively affects the dynamic balance in professional handball players, but it has no effect on flexibility, agility, muscle strength and functional jump. Due to the existence of the relationship between the dynamic balance and the lower extremity, it is recommended to implement the PEP training program in order to improve the dynamic balance in women's handball players.

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