sciendo

Original Paper

Biomedical Human Kinetics, 16, 29–40, 2024
DOI: 10.2478/bhk-2024-0004

The effect of a 12-week functional training program on functional movement patterns and dynamic balance in young elite ice hockey players

Anna Bieniec[1], Małgorzata Grabara[2]

[1] Department of Health-related Physical Activity and Tourism, Jerzy Kukuczka Academy of Physical Education in Katowice, Katowice, Poland; [2] Institute of Sport Science, Jerzy Kukuczka Academy of Physical Education in Katowice, Katowice, Poland

Abstract

Study aim: This study examined the effects of a 12-week functional training (FT) program on basic movement patterns and dynamic balance in hockey players.
Material and methods: Forty-three male ice hockey players aged 16.2 ± 0.76 years, were allocated into the experimental (EG) or control (CG) groups. The EG underwent additional 60-minute supervised FT sessions twice weekly, while the CG had an additional 60-minute team game class and swimming class. Fundamental movement patterns were assessed using the functional movement screening (FMS^{TM}), whereas dynamic balance was assessed by the Y-balance test (YBT).
Results: After completion of the FT program, the hockey players assigned to the EG achieved higher results in the deep squat ($p = 0.0143$), hurdle step ($p = 0.0002$), in-line lunge ($p = 0.0082$), shoulder mobility ($p = 0.0455$), and rotatory stability tests ($p = 0.0253$), had higher total FMS^{TM} scores ($p = 0.0003$), and less asymmetry ($p = 0.0032$) than at baseline. They improved all of the normalized scores in YBT. The hockey players assigned to the CG did not improve their results, but their performance decreased in the hurdle step test ($p = 0.0082$), and they showed more asymmetry ($p = 0.0124$) than at baseline.
Conclusions: The implementation of FT can lead to significant improvements in fundamental movement patterns and dynamic balance among ice hockey players. This suggests that implementing FT can enhance fundamental movement patterns in athletes and should be considered an integral part of sports training. By integrating FT into regular training routines, athletes across different sports may potentially improve their movement patterns, thereby enhancing their overall performance and reducing the risk of injury.

Key words: Athletic performance – Sport training programs – Asymmetries

Introduction

Ice hockey is a fast and very dynamic team sport with high demands on the level of physical and mental fitness [33]. During the game, ice hockey players repeatedly perform very intense speed and strength efforts. They spend 45 and 60 seconds on the ice, after which they go down to the box to take shifts. Ice hockey players skate in all directions, making quick and frequent changes of direction, accelerations, backward skating, sudden braking, and body checking [13]. While skating, a hockey player adopts a posture with the torso slightly bent forward, and the lower limbs bent at the knee and hip joints. Each player has his or her preference for the side of holding the stick. The grip can be left- or right-handed, not always associated with the dominant upper limb. A one-sided grip may contribute to postural asymmetry, and restricted mobility which can lead to overload during adolescence [8, 26]. Competition in ice hockey predisposes the athlete to premature and chronic fatigue [33]. The prevalence of dynamics, speed, and high loads due to external forces makes hockey a game with a high risk of injury.

The development of an athlete is a multi-stage process. Previous studies have emphasized the need for the development of fundamental motor skills and general fitness, including fitness endurance, coordination, mobility, balance, strength, and speed in young athletes to further

Author's address Małgorzata Grabara, Institute of Sport Science, Jerzy Kukuczka Academy of Physical Education in Katowice, 40–065 Katowice, Poland m.grabara@awf.katowice.pl

improve sport-specific skills [18]. Training programs, especially for children and adolescents who intensively practice their chosen sports, should be well thought out, optimized, and monitored. Monitoring of progress using periodic tests and examinations that determine actual physical fitness and identify possible deficits and limitations provide guidelines for further programming and individualization of training [29, 45]. The specifics of each sport require adopting specific and often asymmetrical positions and maintaining them, which can promote the work of only certain muscle groups at different intensities. This has an impact on the athlete's posture and specific movement patterns. Significant loads and adaptive changes occurring in the body of a young athlete can contribute to the development of asymmetries in posture, and the changes that occur during this period of growth will translate into subsequent periods of ontogenesis [34, 43].

One increasingly utilized training method in current sports practice is functional training (FT). FT emphasizes the neuromusculoskeletal system, prioritizing movements over individual muscles, and aims to enhance functional movements and athletic performance in specific sports or physical activities [9, 45, 49]. The concept of FT includes an activity aimed at a planned sequence of exercises to learn correct and controlled movements that are necessary as a foundation for more integrated movements [6]. FT induces adaptations in the central nervous system, enhancing synchronization and activation of agonists, antagonists, stabilizers, and synergists in functional tasks [41]. Sport-specific FT aims to prepare the musculoskeletal system and the joint and ligamentous apparatus for training and competition loads to develop the athlete's highest fitness potential with minimized risk of injury. In athletes, improving functional deficits during the developmental period can bring many benefits from the perspective of a long-term sports career [6].

The Functional Movement Screening (FMS^{TM}) corrective system was designed to eliminate asymmetry and re-educate dysfunctional and compensatory movement patterns [10, 11], which has proven effective in athletes with abnormal movement patterns [32]. FT exercises, performed over a full range of motion (ROM), promote motor control, and train the motor skills required in the target movement, such as strength, mobility, balance, and coordination [1].

Given the unnatural and asymmetric body positioning in skating, functional exercises are beneficial for young players to prevent the development of asymmetric movement patterns [4, 11]. Previous studies have demonstrated that FT programs improved FMS^{TM} [45] and Y-Balance final scores [3, 40] and reduced the number of asymmetries [24]. Therefore, FT appears to be an appropriate choice for young hockey players, aiming to achieve improvement in movement patterns and dynamic balance.

This study addresses a gap in the literature by examining the functional assessment and effects of FT among young elite ice hockey players. FMS^{TM} and Y-Balance tests (YBT) were conducted prior to the implementation of FT to identify the most common deficits. FT was subsequently implemented for an experimental group of young ice hockey players. The aim of this study was to determine whether the implemented FT enhances performance in functional tests after a 12-week period, and thus contributes to the improvement of movement patterns and dynamic balance. It was hypothesized that the hockey players would demonstrate improved functional movement patterns and dynamic balance following the 12-week training period.

Material and methods

Experimental approach to the problem

To investigate the effect of a 12-week functional training program on functional movement patterns and dynamic balance, a randomized controlled trial design was used in elite ice hockey players. Participants were randomly assigned to either the experimental or control group.

This study was comprised of three phases: (I) pre-testing; (II) an intervention: the experimental group underwent 60-minute supervised FT sessions twice a week, while the control group participated in one 60-minute team game (volleyball, basketball, or soccer) and one 60-minute swimming session per week; and (III) post-testing.

Participants

This study involved forty-three elite male ice hockey players, aged between 15 to 18 years. The participants in the experimental group had a mean age of 16 ± 0.72 years, a mean body mass of 78.8 ± 4.92 kg, and a mean body height of 183.6 ± 4.63 cm. Conversely, the participants in the control group had a mean age of 16.3 ± 0.8 years, a mean body mass of 81.2 ± 7.04 kg, and a mean body height of 181.1 ± 7.11 cm. No significant differences were found in these parameters between the groups. All participants were students in the first and second grades at the Polish Ice Hockey Federation's Sports School in Katowice, Poland. The training experience of the athletes ranged from 7 to 9 years.

The required sample size for this investigation was ascertained using G*Power software, version 3.1.9.7, a product of Heinrich Heine University in Düsseldorf, Germany. The computation parameters included an anticipated effect size of 0.4, an alpha error probability of 0.05, and a test power of 0.8. These specifications yielded a required total sample size of forty-one.

The criteria for participant inclusion in the study were as follows: voluntary consent to participate in the study, no

injuries sustained within the past six months, no absences from competitions exceeding 30 days, no surgical procedures undergone within the past 12 months, active participation in all tests, trainings, and scheduled activities.

The hockey players had never been tested with the Functional Movement Screen™ (FMS™) or the Y-Balance tests before starting the 12-week Functional Training (FT) program. They were also unfamiliar with these tests. The study was approved by the Bioethics Committee of the Jerzy Kukuczka Academy of Physical Education in Katowice (certificate of approval No. KB 2/2017) and conformed to the standards set by the Declaration of Helsinki. All participants and their parents/legal guardians were informed about the type and the aim of the study, and they provided written informed consent before participating in the study.

Methods

Anthropometric measurements were used to measure body height (BH) and body mass (BM) of the participants. BH was measured using an anthropometer, whereas BM was evaluated using a Tanita-410 body composition analyzer (Tokyo, Japan).

Fundamental movement patterns were assessed using FMS™ [10, 11] and are divided into three global patterns (deep squat, hurdle step, in-line lunge), two mobility patterns (shoulder mobility, active straight leg raise,) and two stability patterns (trunk stability push-up, and rotary stability tests) [10, 11]. Participants had three attempts at each sub-test and the best score was recorded. Sub-tests 2, 3, 4, 5, and 7 were performed bilaterally to detect potential asymmetries. These sub-tests were carried out separately for the right and left sides, and if the results differed, the lower score was taken as the final result for a given test. The scores ranged from zero to three, with three being the best possible score. The score from all sub-tests was summed, with a maximum score of 21 points. The participant was given a score of zero if, at any time during testing, they reported pain anywhere in the body. A score of one was given if the participant was unable to complete the movement pattern or was unable to assume the position to perform the movement. A score of two was given if the participant performed the tested movement with compensations, and a score of three was given if the participant performed the correct tested movement. The sub-tests numbered 4, 6, and 7 have additional clearing screens that are graded as positive (the participant reports pain during the screening movement), or negative (the participant feels no pain). If the clearing test is positive, this result affects the particular test it is associated with, and the final score for that test is zero [10, 11]. Previous studies have shown that FMS™ has high intrarater and interrater reliability [44], and is a reliable test for young elite hockey players [39]. The overall assessment of the FMS™ was conducted by a physiotherapist with a certificate of completion of the course and passing the FMS exam, and with 7 years of experience.

Dynamic balance in the anterior, posteromedial, and posterolateral directions was assessed by the lower quarter Y-balance test (YBT). The YBT was performed on a Y-shaped device. The device consists of the central platform and reach indicators which are pushed by the tested person. The participant performed three successful reaches, and the maximal reach distance in each direction was analyzed. The testing order was: right anterior (the right stance leg), left anterior, right posteromedial, left posteromedial, right posterolateral, and left posterolateral reach. The participant was not allowed to kick the reach indicator or to use it for support. If the tested athlete was not able to perform 3 attempts according to the above criteria, the investigator did not record that direction, no data was collected, and another attempt was made after waiting 20 seconds [27, 40]. Participants were able to watch a video with instructions on how to take the test, and after the presentation they could take a test, trying to stick to the listed rules.

Reach distance was measured from the most distal part of the toes in the standing position to the most distal part of the foot reaching in the anterior, posterior-lateral, and posterior-medial directions. The distances of each reach were normalized to the relative length of the lower limb following the formula (given in %):

$$Normalized\ score = \frac{reach\ (\text{cm})}{lower\ limb\ length\ (\text{cm})} \times 100\%$$

Values were expressed in centimeters, and the differences between the right and left leg were provided as absolute values. Scores were normalized by dividing the directional means by a participant's leg length. The relative length of the lower limb was measured with a tape measure from the anterior superior iliac spine (ASIS) to the medial ankle in the supine position [25]. The largest reach scores (in cm) for each limb in all directions were also included in the analysis. The difference in cm between the reach for the right and left limbs was also calculated. A difference of 4 cm or more between the reaches of the left and right lower limbs is considered a value above which the risk of injury increases [27, 42]. The composite score (in %) was obtained by taking the mean of the reach scores in all directions for each limb (anterior + posterior-medial + posterior-lateral).

$$Composite\ score\ of\ all\ directions = \frac{3\ reach\ scores}{3 \times lower\ limb\ length} \times 100\%$$

YBT has good to excellent intrarater and interrater reliability and is a reliable test for measuring dynamic balance [40].

Procedures

Preliminary tests were conducted in September, a period when the players were already engaged in regular training and school activities, preparing for the ice hockey league that began in late September. Technical trainings on the ice were conducted five times a week in the mornings. Sparring matches were held every two weeks. Since the league had started, the team was already playing regular games 1-2 times a week. Additional classes, such as FT for the E group or team games and swimming classes for the C group, were held 2 or 3 days before each match. Training volumes and loads were standardized and consistent across both groups.

Functional training program. The first part of FMS™ and YBT showed the areas of movement limitations that led to lower results of tests performed by young hockey players. The application of the training intervention in the experimental group was provided for two 60-minute training sessions per week for 12 weeks. The classes were carefully planned and monitored by the instructors to ensure that the athletes performed the exercises accurately. The training program was based on the system of corrective exercises proposed by the author of FMS™ Gray Cook [10, 11], physiotherapeutic exercises, and FT exercises implemented in the training of selected sports [19, 45]. Training sessions were scheduled on Mondays and Thursdays. Each class had a specific goal and methodology. The sessions were jointly conducted by a physiotherapist with a qualification of an NCSC (National Certificate in Strength & Conditioning) and a technical hockey coach. The functional exercises implemented in the sessions represent a linear path from mobility and stability exercises to pattern integration, using an external load, and dynamic plyometric exercises. Table 1 presents the FT program used in the experimental group.

Statistical analysis

The results were expressed as means with standard deviations (M ± SD), confidence intervals (-95% to 95%), minimum and maximum values, or described using frequencies, medians, and lower and upper quartiles. The normality of distributions and homogeneity of variance were tested using the Shapiro-Wilk test and Levene's test, respectively. Differences in YBT between experimental and control groups were analyzed using the Mann-Whitney U test or the t-test. Due to the ordinal scale of the FMS™ results, the Mann-Whitney U was used to compare results between groups. Differences between pre-tests and posttests in YBT were analyzed using the paired t-test or the Wilcoxon signed-rank test. Differences between the FMS™ trials were analyzed by the Wilcoxon signed-rank test.

The effect size was evaluated using Cohen's d (*dc*) index (the t-test, paired t-test), or r index (the Mann-Whitney U test, the Wilcoxon signed-rank test). For Cohen's d value, the interpretation of effect size was as follows: a small effect from 0.2 to <0.5, a medium effect from 0.5 to <0.8, and a large effect ≥0.8. For r value, the interpretation of effect size was as follows: a small effect from 0.1 to <0.3, a medium effect from 0.3 to <0.5, and a large effect ≥0.5.

The level of significance in all tests was set at $\alpha = 0.05$. The statistical analysis was performed using PS Imago Pro 7.0 software (IBM SPSS Statistics 27).

Table 1. Shortened functional training program (FT)

FT program	Workout methods
1. Breathing exercises (applied from 1st week of FT)	Breathing exercises over 3–4 minutes, 2–3 exercises, low intensity.
2. Mobilizations (applied from 1st week of FT)	Musculo-fascial relaxation using a foam roller and lacrosse ball, PIR (post-isometric relaxation of muscles with increased tension), mobilizations of the thoracic spine, shoulder girdle mobilizations, shoulder retraction exercises, relaxation of the lumbar spine, posterior band mobilizations, increasing hip and ankle joints mobility ranges; 4–6 exercises, 1 set, 6–8 repetitions every exercise, low to moderate intensity.
3. Stabilization exercises (applied from 1st week of FT)	Activation of the deep muscles of the pelvic-hip-lumbar complex, activation of gluteal muscles, and the rotator cone, stabilization exercises, static and dynamic balance exercises; 4–6 exercises, 1 set, 6–8 repetitions every exercise, low to moderate intensity.
4. Integration of movements patterns, exercises with extra load (applied from 4th week of FT)	Unilateral and bilateral squats, dead lift, hip thrust, pulling and pushing patterns, rotational, and anti-rotational patterns (chooping, lifting), weighted strength patterns; 3–5 exercises, 3–4 sets, 6–8 repetitions every exercise, moderate to high intensity.
5. Agility exercises and plyometric exercises (applied from 6th week of FT)	Track and field exercises (coordination ladder exercises, skips, half skips, wall drills, plyometric exercises (vertical, horizontal); 4–6 exercises, 6–8 sets, 4–6 repetitions for each exercise, high to very high intensity.

Results

Preliminary results

The assessment of the functional status of young hockey players conducted before the training program revealed that a total FMS^{TM} score was relatively low. Of all tested ice hockey players, twenty-four (55.8%) had a total FMS^{TM} score of ≤14, seventeen (39.5%) participants had a total score of 15–17, and only two (4.7%) of all participants had a total score of >17. The frequencies of each FMS^{TM} sub-test result for all participants are shown in Table 2. The FMS^{TM} sub-tests in which participants achieved the lowest scores were those that tested rotatory stability, in-line lunge, and hurdle step.

The descriptive analysis for the FMS^{TM} sub-tests and total scores is presented in Table 2. The analysis revealed a statistically significant difference in trunk stability push-up ($p = 0.031$; $r = 0.22$). Players from the experimental group were more likely to achieve higher scores on this test than those from the control group. However, the effect size was small.

The results of YBT are presented in Table 3. The analysis indicated a significant difference in the posteromedial reach between the right and left legs ($p = 0.0015$, $r = 0.48$) between the groups.

Outcomes

The applied 12-week FT improved the functional status of global patterns in the FMS^{TM} and YBT. After completion of the FT program, the hockey players assigned to the experimental group achieved significantly higher results in five of seven FMS^{TM} sub-tests, higher total FMS^{TM} scores, and less asymmetry than at baseline. The hockey players assigned to the control group did not improve their results after their training program, but their performance decreased in the hurdle step test and showed more asymmetry than before the training program (Table 4).

After completing the FT program, the hockey players from the experimental group also improved their scores in YBT. The range difference between the right and left legs in the posterolateral direction was significantly lower, and in the normalized scores, these hockey players obtained better results than before the training. It should be noted that the effect size was large for most Y-balance parameters. Hockey players assigned to the control group did not improve their performance. The analysis showed that these players scored significantly worse in normalized scores in the posterolateral and posteromedial (right leg) direction after the training program than before (Table 5).

The analysis showed that the total score of FMS^{TM} ($p < 0.0001$, $r = 0.61$), the number of asymmetries ($p < 0.0001$, $r = 0.65$), and most of the results of FMS^{TM} sub-tests, i.e. hurdle step ($p = 0.0001$, $r = 0.59$), in-line

Table 2. Preliminary results of functional movement screening (FMS^{TM}) in the experimental and control groups, and in all participants

FMS^{TM} sub-tests and total score	Experimental group (n = 22)			Control group (n = 21)			All participants (n = 43)		
	M ± SD	Mediana	Lower-upper quartiles	M ± SD	Mediana	Lower-upper quartiles	1 point (n)	2 points (n)	3 points (n)
Deep squat	2.00 ± 0.53	2	2–2	2.05 ± 0.59	2	2–2	6	30	7
Hurdle step	1.77 ± 0.43	2	2–2	1.95 ± 0.59	2	2–2	9	31	3
In-line lunge	1.95 ± 0.49	2	2–2	1.76 ± 0.62	2	1–2	10	29	4
Active straight leg rise	2.23 ± 0.61	2	2–3	2.05 ± 0.22	2	2–2	2	33	8
Shoulder mobility	2.50 ± 0.51	2.5	2–3	2.19 ± 0.51	2	2–2	1	26	16
Trunk stability push-up	**2.27 ± 0.46***	2	2–3	**2.00 ± 0.32***	2	2–2	1	35	7
Rotary stability	1.77 ± 0.43	2	2–2	1.67 ± 0.48	2	1–2	12	31	0
Asymmetries	1.00 ± 0.87	1	0–2	1.48 ± 1.03	2	1–2			
FMS^{TM} total score	14.64 ± 2.13	14.5	13–17	13.71 ± 2.33	14	12–15			

M ± SD – mean and standard deviations; statistically significant differences between the experimental and the control group are bolded; *$p < 0.05$; p-value calculated using the Mann-Whitney U test.

Table 3. Preliminary results of Y-balance test (YBT) in the experimental and control groups

Y-balance sub-tests	Experimental group (n = 22)			Control group (n = 21)		
	M ± SD	C.I. –95%–95%	Min-max	M ± SD	C.I. –95%–95%	Min-max
Reach differences between right and left leg [cm]						
Anterior	4.14 ± 3.64	2.52 – 5.75	0–11	4.95 ± 3.07	3.55–6.35	0–12
Posterolateral	6.73 ± 4.68	4.65–8.80	1–20	6.24 ± 4.18	4.33–8.14	1–18
Posteromedial	**3.59 ± 3.87****	1.87–5.31	0–15	**8.81 ± 6.77****	5.73–11.89	0–30
Composite	3.4 ± 2.32	2.37–4.43	0.01–8.5	4.91 ± 3.32	3.4–6.42	0.35–10.61
Normalized scores [% leg length]						
Anterior R	55.84 ± 8.23	52.19–59.50	42.71–74.26	53.21 ± 8.41	49.38–57.04	41.41–71.88
Anterior L	55.71 ± 6.92	52.65–58.78	42.11–69.70	51.9 ± 10.45	47.15–56.66	30–71.88
Posterolateral R	122.52 ± 11.83	117.28–127.77	102.11–149.5	124.28 ± 14.92	117.49–131.07	101.98–153.13
Posterolateral L	124.43 ± 12.79	118.76–130.1	94.79–150	121.06 ± 14.54	114.44–127.68	101.01–152.08
Posteromedial R	121.42 ± 11.5	116.32–126.52	101.96–148.51	124.29 ± 17.28	116.42–132.16	99.01–175.64
Posteromedial L	123.55 ± 10.82	118.76–128.35	103.88–144	118.21 ± 18.54	109.77–126.65	86.87–160

M ± SD – mean and standard deviations; C.I. – confidence interval (–95%–95%); R – right leg; L – left leg; statistically significant differences between the experimental and control groups are bolded; *p < 0.05; **p < 0.01; ***p < 0.001; p-value calculated using the Mann-Whitney U test or t-test.

Table 4. The intra-group comparison between the functional movement screening (FMS^{TM}) results obtained before and after the applied 12-week training program and the inter-group comparison between pre-test and posttest

FMS^{TM} sub-tests and total score	Intra-group differences				Inter-group differences
	Experimental group (n = 22)		Control group (n = 21)		
	Pre-to-posttest difference (M ± SD)	Sig.	Pre-to-posttest difference (M ± SD)	Sig.	Sig.
Deep squat	–0.27 ± 0.46	p = 0.0143 r = 0.52	0.14 ± 0.57	ns	p = 0.0149 r = 0.37
Hurdle step	–0.64 ± 0.49	p = 0.0002 r = 0.80	0.33 ± 0.48	p = 0.0082 r = 0.58	p < 0.0001 r = 0.71
In-line lunge	–0.32 ± 0.48	p = 0.0082 r = 0.56	0.05 ± 0.22	ns	p = 0.0036 r = 0.44
Active straight leg rise	–0.18 ± 0.59	ns	–0.10 ± 0.30	ns	ns
Shoulder mobility	–0.18 ± 0.39	p = 0.0455 r = 0.43	0.10 ± 0.30	ns	p = 0.0154 r = 0.37
Trunk stability push-up	–0.18 ± 0.59	ns	–0.14 ± 0.36	ns	ns
Rotary stability	–0.23 ± 0.43	p = 0.0253 r = 0.48	0.00 ± 0.32	ns	ns
Asymmetries	0.64 ± 0.79	p = 0.0032 r = 0.63	–0.48 ± 0.75	p = 0.0124 r = 0.55	p = 0.0001 r = 0.60
FMS^{TM} total score	–1.82 ± 1.44	p = 0.0003 r = 0.77	0.29 ± 1.10	ns	p < 0.0001 r = 0.63

M ± SD – mean and standard deviations; Sig. – significance; p – p-values calculated using the Wilcoxon signed-rank test (intra-group), and Mann-Whitney U test (inter-group); r – r index: 0.1 to <0.3 – small effect, 0.3 to <0.5 – medium effect, ≥0.5 – large effect; ns – not significant

Table 5. The intra-group comparison between the Y-balance (YBT) results obtained before and after the applied 12-week training program and the inter-group comparison between pre-test and posttest

Y-balance sub-tests	Intra-group differences				Inter-group differences
	Experimental group (n = 22)		Control group (n = 21)		
	Pre-to-posttest difference (M ± SD)	Sig.	Pre-to-posttest difference (M ± SD)	Sig.	Sig.
Reach differences between right and left leg [cm]					
Anterior	1.45 ± 3.45	ns	–0.57 ± 2.93	ns	ns
Posterolateral	2.23 ± 2.96	p = 0.0047 r = 0.60	–0.48 ± 4.06	ns	p = 0.0163 dc = 0.76
Posteromedial	0.14 ± 3.59	ns	1.24 ± 3.00	ns	ns
Composite	0.96 ± 2.09	ns	–0.13 ± 3.06	ns	ns
Normalized scores [% leg length]					
Anterior R	3.84 ± 3.19	p < 0.0001 dc = 1.23	–0.11 ± 2.27	ns	p < 0.0001 dc = 1.43
Anterior L	3.91 ± 5.13	p = 0.0018 dc = 0.78	–1.79 ± 6.25	ns	p = 0.0013 r = 0.49
Posterolateral R	8.64 ± 9.76	p = 0.0005 dc = 0.91	–2.52 ± 4.46	p = 0.0176 dc = 1.16	p < 0.0001 r = 0.65
Posterolateral L	6.86 ± 7.26	p = 0.0002 dc = 0.97	–2.12 ± 5.74	ns	p<0.0001 r = 0.63
Posteromedial R	5.22 ± 7.37	p = 0.0032 dc = 0.72	–2.41 ± 3.54	p = 0.0062 r = 0.60	p = 0.0001 r = 0.58
Posteromedial L	4.67 ± 7.51	p = 0.0082 dc = 0.64	–1.11 ± 5.15	ns	p = 0.0030 r = 0.44

M ± SD – mean and standard deviations; Sig. – significance; p – p-values calculated using the paired t test or Wilcoxon signed-rank test (intra-group), and t-test or Mann-Whitney U test (inter-group); r – r index: 0.1 to <0.3 – small effect, 0.3 to <0.5 – medium effect, ≥0.5 – large effect; dc – Cohens' d: 0.2 to <0.5 – small effect, 0.5 to <0.8 – medium effect, ≥0.8 – large effect; ns – not significant.

Table 6. Final results of functional movement screening (FMS^{TM}) in the experimental and control groups

FMS^{TM} sub-tests and total score	Experimental group (n = 22)			Control group (n = 21)		
	M ± SD	Mediana	Lower-upper quartiles	M ± SD	Mediana	Lower-upper quartiles
Deep squat	**2.27 ± 0.46***	2	2–3	**1.90 ± 0.54***	2	2–2
Hurdle step	**2.41 ± 0.50*****	2	2–3	**1.62 ± 0.59*****	2	1–2
In-line lunge	**2.27 ± 0.46****	2	2–3	**1.71 ± 0.56****	2	1–2
Active straight leg rise	2.41 ± 0.59	2	2–3	2.14 ± 0.36	2	2–2
Shoulder mobility	**2.68 ± 0.48****	3	2–3	**2.10 ± 0.62****	2	2–2
Trunk stability push-up	**2.45 ± 0.51***	2	2–3	**2.14 ± 0.36***	2	2–2
Rotary stability	**2.00 ± 0.00****	2	2–2	**1.67 ± 0.48****	2	1–2
Asymmetries	**0.36 ± 0.49*****	0	0–1	**1.95 ± 1.20*****	2	1–3
FMS^{TM} total score	**16.45 ± 1.90*****	16.5	15–18	**13.43 ± 2.48*****	13	12–15

M ± SD – mean and standard deviations; statistically significant differences between the experimental and control groups are bolded; *p < 0.05; **p < 0.01; ***p < 0.001; p-value calculated using the Mann-Whitney U test

Table 7. Final results of the Y-balance test (YBT) in the experimental and control groups

Y-balance sub-tests	Experimental group (n = 22)			Control group (n = 21)		
	M ± SD	C.I. –95%–95%	Min-max	M ± SD	C.I. –95%–95%	Min-max
Reach differences between right and left leg [cm]						
Anterior	**2.68 ± 2.64*** **	1.51–3.85	0–11	**5.52 ± 3.88*** **	3.76–7.29	1–17
Posterolateral	**4.50 ± 4.72***	2.41–6.59	0–17	**6.71 ± 5***	4.44–8.99	1–24
Posteromedial	**3.45 ± 2.5***	2.35–4.56	0–10	**7.57 ± 6.75***	4.50–10.64	0–29
Composite	**2.44 ± 2.16***	1.48–3.39	0.04–9.59	**5.04 ± 3.82***	3.30–6.78	0.35–15.03
Normalized scores [% leg length]						
Anterior R	**59.68 ± 8.29***	56.01–63.36	45.83–73.68	**53.10 ± 8.99***	49.01–57.2	38.61–75
Anterior L	**59.62 ± 7.79****	56.17–63.08	45.26–70.71	**50.12 ± 9.81****	45.65–54.58	33–76.04
Posterolateral R	**131.16 ± 12.70***	125.53–136.80	104.17–153.47	**121.76 ± 15.49***	114.71–128.81	101.98–156.25
Posterolateral L	**131.28 ± 14.37***	124.91–137.66	93.75–154.26	**118.95 ± 16.92***	111.24–126.65	94.12–155.21
Posteromedial R	126.64 ± 11.66	121.47–131.81	100.99–152.48	121.88 ± 16.84	114.22–129.55	100.00–171.79
Posteromedial L	**128.23 ± 12.30***	122.77–133.68	100.00–149.00	**117.10 ± 17.84***	108.98–125.22	86.73–156.25

M ± SD – mean and standard deviations; C.I. – confidence interval (–95%–95%); R – right leg; L – left leg; statistically significant differences between the experimental and control groups are bolded; *p < 0.05; **p < 0.01; ***p < 0.001; p-value calculated using the Mann-Whitney U test or t-test.

lunge (p = 0.0015, r = 0.48), shoulder mobility (p = 0.0021, r = 0.47), rotatory stability (p = 0.0034, r = 0.45), trunk stability push-up (p = 0.0279, r = 0.34), and deep squat (p = 0.0241, r = 0.34) obtained after the FT program differed between the experimental and control groups (table 6).

Most of the Y-balance results, i.e. differences in the reach between right and left legs in the anterior (p = 0.0060, r = 0.41), posterolateral (p = 0.0337, r = 0.32), posteromedial (p = 0.0277, r = 0.33) directions, composite scores (p = 0.046, r = 0.37), and normalized scores in the anterior (R: p = 0.0167, dc = 0.76, L: p = 0.0011, dc = 1.07), posterolateral (R: p = 0.0350, dc = 0.66, L: p = 0.0135, dc = 0.79), and posteromedial (L: p = 0.0214, dc = 0.73) directions obtained after the FT program were statistically significant between the experimental and control groups. Hockey players assigned to the experimental group had lower asymmetries between the right and left legs and showed better performance in reaching in all directions than those assigned to the control group (Table 7).

Discussion

The primary aim of this study was to investigate the effects of a 12-week FT program on basic movement patterns and dynamic balance in young elite hockey players. Before the implementation of the FT program, a functional assessment was conducted using FMS^{TM} and the YBT. The FT program was then meticulously designed based on the preliminary analysis these results. This analysis revealed numerous deficits in the mobility of various joints, including the shoulder girdle, thoracic spine, hip, and ankle joints, as well as asymmetries in the unilateral tests. These functional limitations were observed in the majority of the tested hockey players. The players performed poorest in tests that required motor control over multiple joints, such as deep squat, hurdle step, in-line lunge as well as in the rotatory stability test. The YBT results also indicated an asymmetry in reach scores between the right and left limbs in the posterolateral and posteromedial directions.

This comprehensive assessment and subsequent design of the FT program aimed to address these identified deficits and improve overall functional performance. According to the FMS^{TM} correction system, mobility is crucial to the correct movement [10, 11]. Mobilizations improve restrictions in joint mobility through the mechanism of joint play by allowing joint sliding and normalizing joint capsule tension [22]. A study by Oleksiak et al. examined whether the hip ROM affects the score on FMS™. The authors showed that as the hip ROM improved, so did the score on the deep squat test and the mobility test of active straight leg raise. Thus, it was concluded that mobilization exercises could increase hip mobility, which would improve performance on individual FMS^{TM} mobility tests [38]. Improvements in FMS^{TM} test scores have been observed following ankle joint mobilization to increase the range of dorsiflexion [16]. A study by Fuglsang showed

that individuals with greater ankle joint range of motion maintain an upright and more stable posture, allowing for a deeper squat by keeping the thighs parallel to the ground [17]. The effectiveness of ankle joint mobilization was also supported by improved FMS^{TM} test scores [51] and anterior reach in the YBT [36].

Optimal performance in the squat, hurdle step, and in-line lunge tests requires an optimal range of motion (ROM) of the thoracic spine with controlled brachial-scapular movement and maintenance of a stable lumbar spine [15]. Optimal mobility of the lower and upper limb joints and postural control are also required [35]. Previous studies have already suggested that limited mobility of the lower limb joints may be a limiting factor in performing deep squats [30]. Limited range of extension and external rotation at the shoulder joint and compensatory lumbar movements caused an incorrect position in the in-line lunge test and the shoulder mobility test. In ice hockey players, daily training is dominated by flexion patterns, with the trunk forward and shoulder and head protraction, which affects the quality of posture [31, 34] and may contribute to the difficulties in maintaining control of a straight thoracic spine. During the performance of the tests, it was noted that the hockey players had limited hip mobility. While performing the hurdle step, in-line lunge, and rotatory stability tests, the hip flexion pattern was compensated by additional movements in the facet joints of the lumbar spine. Given that ice hockey requires players to assume asymmetric positions, numerous asymmetries were noted in the scores of unilateral tests.

The final examinations showed that the FT program improved the FMS^{TM} and YBT scores of hockey players from the experimental group. They improved the quality of performance of movement tasks in each test and scored more points on each test. Significantly better results in the second measurement compared to the first were obtained in the deep squat, hurdle step, in-line lunge, shoulder mobility, and rotational stability tests. The athletes significantly improved the total FMS^{TM} score and reduced the number of asymmetries. Thus, the effect of FT in the experimental group is evident. Furthermore, in the control group, we noted significantly more asymmetry in the second measurement compared to the first, and a deterioration in the hurdle step test. The above results support our hypothesis that the FT program would improve the FMS^{TM} test scores.

The YBT scores also improved after FT. The improvement in composite score after the training period indicates that the athletes from the experimental group had greater ranges of motion in all three directions tested in YBT, in both the right and left lower limbs. An important effect is the significant reduction in reach asymmetry between the right and left lower limbs, especially in the posterolateral direction, between which the asymmetry was significant at the first measurement.

The FT program focused on correcting the weakest and asymmetric movement tasks. Mobilization and stabilization exercises in the training of young hockey players were preceded by muscle-fatigue relaxation, breathing exercises, and MET techniques (muscle energy techniques-PIR, IR). This was to help improve joint ROM and motor control, resulting in higher scores on FMS^{TM} and the YBT. Bradley and Esformes found an association between diaphragmatic breathing patterns and higher scores on the FMS^{TM} test. FMS^{TM} scores were significantly higher among diaphragmatic than thoracic breathing subjects [7]. Cowen showed that a 6-week yoga program that focused on breathing techniques and breath control significantly improved FMS^{TM} scores in firefighters [12].

In our study, the hockey players in the experimental group significantly improved their test scores in the second measurement compared to the first, gaining better control of their movement at the extremes of the range in both FMS^{TM} and the YBT test. Our FT program included exercises to shape mobility and balance. Mobility exercises required motor control in the final ranges of motion with proper breathing. Optimal proximal stability allows for safe distal movement [23]. During exercise, the deep muscles of the trunk and pelvis are responsible for movement control, maintaining spinal and pelvic stability, and influencing force generation and its transfer to the limbs [14].

The study, which examined the effects of the FMS^{TM} training program among elite male baseball players, found improvements in strength and flexibility [45]. The intervention program that focused on resistance training improved FMS^{TM} test scores in mixed martial arts (MMA) athletes [3]. In a study by Vitale, the inclusion of additional exercises to improve deep muscle strength and movement control of the hip-pelvic-lumbar complex in skiers improved lower limb ranges of motion in each direction of the YBT and the composite Y-Balance scores in the experimental group, while these results worsened in the control group [48]. Laws et al. found an improvement in FMS^{TM} scores in recreational runners after an intervention program that focused on clinical Pilates [28]. These results support the idea that improving functional motor control through core strengthening can improve functional movement patterns, and potentially reduce injury risk. In a group of tennis players, there were improved FMS^{TM} scores after FT exercises consisting of mobility-enhancing movements and utilizing a kinetic chain based on movement pattern exercises (push, pull, rotations, squats, lifts, jumps), which the athlete performed in 3 planes. This study also indicated a significantly greater effect of FT compared to traditional training [50]. Similar improvements in FMS^{TM} scores after corrective intervention were obtained in football players [24], firefighters [46], and soldiers [20]. The majority of human movements are unilateral. Therefore, the implementation of unilateral exercises may also have affected the progression of dynamic

balance in athletes in the experimental group. Similarly, in our program, we put a lot of focus on plyometrics. Towards the end, we incorporated unilateral plyometric exercises, which required a lot of deep muscle activity, coordination, and optimal muscle timing during the landing phase.

Benis et al. found improvements in female basketball players in the posteromedial, posterolateral, and composite scores of YBT following an 8-week neuromuscular training program based on core exercises and plyometrics [2]. Bouteraa et al. also reported an improvement in YBT scores after an 8-week balance and plyometrics training program in adolescent female basketball players [5]. Coordination training with a training rope was used by Trecroci et al. in soccer players as an accent to end the warm-up. The authors found an improvement in the YBT composite score after an 8-week exercise program [47]. Hammami et al. combined balance and plyometric exercises in youth soccer players and found improvements in YBT scores in all directions after an 8-week exercise program [21]. O'Malley et al. implemented a neuromuscular exercise program twice a week in soccer and hurling players, with strength, functional, balance, and plyometric exercises included in a 15-minute warm-up conducted at the beginning of training for 8 weeks. The program used positively improved dynamic balance scores for all directions in the YBT except for the left anterior [37].

Strengths and limitations of the study

The study provides important insights into sports training, specifically the effect of the FT program on improving movement patterns and dynamic balance in ice hockey players.

There are several limitations of this study. First, FMS^{TM} is a screening test that does not allow for diagnosis but only indicates certain limitations and asymmetries. The second limitation is the inability to conduct a follow-up study after 6 weeks. Thirdly, we did not measure ranges of motion with a goniometer, which could evaluate the angular ranges in each joint during movements. Another limitation of the study is the lack of precise assessment of the intensity of both the FT, which was carried out in the experimental group, and the team games and swimming training carried out in the control group. We assumed that the training loads were similar. Finally, another limitation of this study is the relatively narrow age range of the athletes included in the study, thus caution should be exercised in generalizing the results. Future studies focusing on the effect of FT should also take into consideration musculoskeletal complaints before the implementation of the training program and determine whether they are caused by limitations and movement deficits, evaluate their intensity, and identify the areas of the body where they occur most frequently. This would allow an assessment of whether the FT contributes to a reduction in these complaints.

Conclusions

The implementation of FT, which includes regularly applied joint mobilization and stabilization exercises, as well as the activation of entire muscle groups in a given pattern, appears to have provided a novel stimulus for the athletes in the experimental group. This is evidenced by the significant improvement in performance in the FMS^{TM} and YBT among ice hockey players.

This suggests that implementing FT can enhance fundamental movement patterns in athletes and should be considered an integral part of sports training. By integrating FT into regular training routines, athletes across different sports may potentially improve their movement patterns, thereby enhancing their overall performance and reducing the risk of injury.

Conflict of interest: Authors state no conflict of interest.

References

1. Beckham S.G., Harper M. (2010) Functional training: Fad or here to stay? *ACSM's Health Fit. J.,* 14: 24–30. DOI: 10.1249/FIT.0b013e3181f8b3b7
2. Benis R., Bonato M., La Torre A. (2016) Elite female basketball players' body-weight neuromuscular training and performance on the Y-balance test. *J. Athl. Train.,* 51: 688–695. DOI: 10.4085/1062-6050-51.12.03
3. Bodden J.G., Needham R.A., Chockalingam N. (2015) The effect of an intervention program on functional movement screen test scores in mixed martial arts athletes. *J. Strength Cond. Res.,* 29: 219–225. DOI: 10.1519/JSC.0b013e3182a480bf
4. Boguszewski D., Jakubowska K., Adamczyk J.G., Ochal A., Bialoszewski D. (2017) Functional assessment of children practicing ice hockey through Functional Movement Screen test. *Phys. Act. Rev.,* 5: 105–112. DOI: 10.16926/par.2017.05.15
5. Bouteraa I., Negra Y., Shephard R.J., Chelly M.S. (2020) Effects of Combined Balance and Plyometric Training on Athletic Performance in Female Basketball Players. *J. Strength Cond. Res.,* 34: 1967–1973. DOI: 10.1519/JSC.0000000000002546
6. Boyle M. (2016) New Functional Training for Sports.
7. Bradley H., Esformes J. (2014) Breathing pattern disorders and functional movement. *Int. J. Sports Phys. Ther.,* 9: 28–39.
8. Bussey M.D. (2010) Does the demand for asymmetric functional lower body postures in lateral sports relate to structural asymmetry of the pelvis? *J. Sci. Med. Sport,* 13: 360–364. DOI: 10.1016/j.jsams.2009.02.010

9. Clark S.C., Rowe N.D., Adnan M., Brown S.M., Mulcahey M.K. (2022) Effective Interventions for Improving Functional Movement Screen Scores Among "High-Risk" Athletes: A Systematic Review. *Int. J. Sports Phys. Ther.,* 17: 131–138. DOI: 10.26603/001c.31001
10. Cook G., Burton L., Hoogenboom B.J., Voight M. (2014) Functional movement screening: the use of fundamental movements as an assessment of function – part 2. *Int. J. Sports Phys. Ther.,* 9: 549–563.
11. Cook G., Burton L., Hoogenboom B.J., Voight M. (2014) Functional movement screening: the use of fundamental movements as an assessment of function – part 1. *Int. J. Sports Phys. Ther.,* 9: 396–409. DOI: 10.1519/JSC.0000000000000757
12. Cowen V.S., Burkett L., Bredimus J., Evans D.R., Lamey S., Neuhauser T., Shojaee L. (2006) A comparative study of Thai massage and Swedish massage relative to physiological and psychological measures. *J. Bodyw. Mov. Ther.,* 10: 266–275. DOI: 10.1016/j.jbmt.2005.08.006
13. Cox M., Miles D., Verde T., Rhodes E. (1995) Applied Physiology of Ice Hockey. *Sport Med.,* 19: 184–201. DOI: 10.2165/00007256-199519030-00004
14. Crossley K.M., Middelkoop M. Van, Callaghan M.J., Collins N.J., Rathleff M.S., Barton C.J. (2016) 2016 Patellofemoral pain consensus statement from the 4th International Patellofemoral Pain Research Retreat, Manchester. Part 2: Recommended physical interventions (exercise, taping, bracing, foot orthoses and combined interventions). *Br. J. Sports Med.,* 50: 844–852. DOI: 10.1136/bjsports-2016-096268
15. Divya, Parveen A., Nuhmani S., Ejaz Hussain M., Hussain Khan M. (2021) Effect of lumbar stabilization exercises and thoracic mobilization with strengthening exercises on pain level, thoracic kyphosis, and functional disability in chronic low back pain. *J. Complement. Integr. Med.,* 18: 419–424. DOI: 10.1515/jcim-2019-0327
16. Ericson M., Kennedy A., Rosentreter K., Turnquist T., Braun S., Claire E. (2014) Effect of deep heating and foam rolling vs. static stretching of the gastrocnemius and soleus complex in improving active ankle dorsiflexion range of motion. *Undergrad Res.,* 10: 64–78.
17. Fuglsang E.I., Telling A.S., Sørensen H. (2017) Effect of ankle mobility and segment ratios on trunk lean in the barbell back squat. *J. Strength Cond. Res.,* 31: 3024–3033. DOI: 10.1519/JSC.0000000000001872
18. Gambetta V. (2007) Athletic Development: The Art & Science of Functional Sports Conditioning. *Hum. Kinet*., 188–189.
19. Garbenytė-Apolinskienė T., Šiupšinskas L., Salatkaitė S., Gudas R., Radvila R. (2018) The effect of integrated training program on functional movements patterns, dynamic stability, biomechanics, and muscle strength of lower limbs in elite young basketball players. *Sport Sci. Health,* 14: 245–250. DOI: 10.1007/s11332-017-0409-y
20. Goss D.L., Christopher G.E., Faulk R.T., Moore J. (2009) Functional training program bridges rehabilitation and return to duty. *J. Spec. Oper. Med.,* 9: 29–48.
21. Hammami R., Granacher U., Makhlouf I., Behm D.G., Chaouachi A. (2016) Sequencing Effects of Balance and Plyometric Training on Physical Performance in Youth Soccer Athletes. *J. Strength Cond. Res.,* 30: 3278–3289. DOI: 10.1519/JSC.0000000000001425
22. Hwangbo P.N., Hwangbo G., Park J., Lee S. (2014) The effect of thoracic joint mobilization and self-stretching exercise on pulmonary functions of patients with chronic neck pain. *J. Phys. Ther. Sci.,* 26: 1783–1786. DOI: 10.1589/jpts.26.1783
23. Kibler W. Ben, Press J.M., Sciascia A. (2006) The role of core stability in athletic function. *Sports Med.,* 36: 189–198. DOI: 10.2165/00007256-200636030-00001
24. Kiesel K., Plisky P., Butler R. (2009) Functional movement test scores improve following a standardized off-season intervention program in professional football players. *Scand. J. Med. Sci. Sport,* 21: 287–292. DOI: 10.1111/j.1600-0838.2009.01038.x
25. Kokinda M., Jesensky M., Kandrac R., Kicura D., Turek M., Chovanova E. (2018) Examination of Age-related Core Stability and Dynamic Balance in Hockey Players. *Sport Mont.,* 16: 21–26. DOI: 10.26773/smj.180604
26. Kokinda M., Kicura D., Kandrac R., Fabian S. (2020) Functional state of the musculoskeletal system and injury rate among ice hockey players. *Int. J. Phys. Educ. Fit. Sport.* DOI: 10.34256/ijpefs2024
27. Krueger H., German N. (2014) The Effectiveness of the Y Balance Test Compared to the Star Excursion Balance Test : A Critically Appraised Topic Implications for Practice , Education Characteristics of Included Studies and Future Research Clinical Bottom Line References Search Strategy. *J. Sport Rehabil.*
28. Laws A., Williams S., Wilson C. (2017) The Effect of Clinical Pilates on Functional Movement in Recreational Runners. *Int. J. Sports Med*., 38: 776–780. DOI: 10.1055/s-0043-111893
29. Lisman P., Nadelen M., Hildebrand E., Leppert K., de la Motte S. (2018) Functional movement screen and Y-Balance test scores across levels of American football players. *Biol. Sport,* 35: 253–260. DOI: 10.5114/biolsport.2018.77825
30. Macrum E., Bell D.R., Boling M., Lewek M., Padua D. (2012) Effect of limiting ankle-dorsiflexion range of motion on lower extremity kinematics and muscle-activation patterns during a squat. *J. Sport Rehabil.,* 21: 144–150. DOI: 10.1123/jsr.21.2.144
31. Majcen Rosker Z., Kristjansson E., Vodicar M., Rosker J. (2021) Postural balance and oculomotor control are influenced by neck kinaesthetic functions in elite ice hockey players. *Gait Posture,* 85: 145–150. DOI: 10.1016/j.gaitpost.2021.01.024

32. Malliaras P., Cook J.L., Kent P. (2006) Reduced ankle dorsiflexion range may increase the risk of patellar tendon injury among volleyball players. *J. Sci. Med. Sport,* 9: 304–309. DOI: 10.1016/j.jsams.2006.03.015
33. Montgomery D.L. (2006) Physiological profile of professional hockey players – A longitudinal comparison. *Appl. Physiol. Nutr. Metab.,* 31: 181–185. DOI: 10.1139/H06-012
34. Mucha D., Smach K., Ambroży T., Gulak S., Mucha T., Makuch R. (2016) The impact of the ice hockey training on the player's posture. *Secur. Econ. Law.,* 12: 47–61.
35. Myer G.D., Kushner A.M., Brent J.L., Schoenfeld B.J., Hugentobler J., Lloyd R.S., Vermeil A., Chu D.A., Harbin J., McGill S.M. (2014) The back squat: A proposed assessment of functional deficits and technical factors that limit performance. *Strength Cond. J.,* 36: 4–27. DOI: 10.1519/SSC.0000000000000103
36. Nakagawa T.H., Petersen R.S. (2018) Relationship of hip and ankle range of motion, trunk muscle endurance with knee valgus and dynamic balance in males. *Phys. Ther. Sport,* 34: 174–179. DOI: 10.1016/j.ptsp.2018.10.006
37. O'Malley E., Murphy J.N.C., Persson U.M., Gissane C., Blake C. (2017) The effects of the gaelic athletic association 15 training program on neuromuscular outcomes in gaelic football and hurling players: A randomized cluster trial. *J. Strength Cond. Res.,* 31: 2119–2130. DOI: 10.1519/JSC.0000000000001564
38. Oleksiak J., Sobianek A., Janiszewski M. (2019) The Effect of Corrective Exercises on the Range of Motion of the Hip Joints and the Result Obtained in the Deep Squat of FMS Test. *Cent. Eur. J. Sport Sci. Med.,* 26: 31–40. DOI: 10.18276/cej.2019.2-03
39. Parenteau-Goudreault E., Gaudreault N., Chambers S., Boisvert C., Grenier A., Gagné G., Balg F. (2014) Functional Movement Screen test (FMS): A reliable screening test for young elite hockey players. *Phys. Ther. Sport,* 15: 169–175. DOI: 10.1016/j.ptsp.2013.10.001
40. Plisky P.J., Gorman P.P., Butler R.J., Kiesel K.B., Underwood F.B., Elkins B. (2009) The reliability of an instrumented device for measuring components of the star excursion balance test. *North Am. J. Sport Phys. Ther.,* 4: 92–99.
41. Sale D.G. (1988) Neural adaptation to resistance training. *Med. Sci. Sports Exerc.,* 20: S135–S145. DOI: 10.1249/00005768-198810001-00009
42. Shaffer S.W., Teyhen D.S., Lorenson C.L., Warren R.L., Koreerat C.M., Straseske C.A., Childs J.D. (2013) Y-balance test: A reliability study involving multiple raters. *Mil. Med.,* 178: 1264–1270. DOI: 10.7205/MILMED-D-13-00222
43. Sławińska T., Rożek K., Ignasiak Z. (2006) Asymetrie ciała w obrębie tułowia dzieci wczesnej specjalizacji sportowej. *Med. Sport,* 22: 97–100.
44. Smith C.A., Chimera N.J., Wright N.J., Warren M. (2013) Interrater and intrarater reliability of the functional movement screen. *J. Strength Cond. Res.,* 27: 982–987. DOI: 10.1519/JSC.0b013e3182606df2
45. Song H-S., Woo S-S., So W-Y., Kim K-.J, Lee J., Kim J-Y. (2014) Effects of 16-week functional movement screen training program on strength and flexibility of elite high school baseball players. *J. Exerc. Rehabil.,* 10: 124–130. DOI: 10.12965/jer.140101
46. Stanek J.M., Dodd D.J., Kelly A.R., Wolfe A.M., Swenson R.A. (2017) Active duty firefighters can improve Functional Movement Screen (FMS) scores following an 8-week individualized client workout program. *Work,* 56: 213–220. DOI: 10.3233/WOR-172493
47. Trecroci A., Cavaggioni L., Caccia R., Alberti G. (2015) Jump rope training: Balance and motor coordination in preadolescent soccer players. *J. Sport Sci. Med.,* 14: 792–798
48. Vitale J.A., La Torre A., Banfi G., Bonato M. (2018) Effects of an 8-week body-weight neuromuscular training on dynamic balance and vertical jump performances in elite junior skiing athletes: A randomized controlled trial. *J. Strength Cond. Res.,* 32: 911–920. DOI: 10.1519/jsc.0000000000002478
49. Weiss T., Kreitinger J., Wilde H., Wiora C., Steege M., Dalleck L., Janot J. (2010) Effect of Functional Resistance Training on Muscular Fitness Outcomes in Young Adults. *J. Exerc. Sci. Fit.,* DOI: 10.1016/S1728-869-X(10)60017-2
50. Yildiz S., Pinar S., Gelen E. (2019) Effects of 8-week functional vs. traditional training on athletic performance and functional movement on prepubertal tennis players. *J. Strength Cond. Res.,* 33: 651–661. DOI: 10.1519/jsc.0000000000002956
51. Yun S.J., Kim M.H., Weon J.H., Kim Y., Jung S.H., Kwon O.Y. (2016) Correlation between toe flexor strength and ankle dorsiflexion rom during the countermovement jump. *J. Phys. Ther. Sci.,* 28: 2241–2244. DOI: 10.1589/jpts.28.2241

Received 24.08.2023
Accepted 26.11.2023

© University of Physical Education, Warsaw, Poland

Acknowledgements

The authors thank the participants for their invaluable contribution to the study.

This study was supported by Jerzy Kukuczka Academy of Physical Education in Katowice, as a part of status research from public funds, Grant No. AWF/INS/ZB2/2023.