



Effects of a preparatory training protocol on the movement and body stability of handball players

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Abstract: Handball is a sport with a high risk of injury, The prevalence of injury is only obtainable through a thorough and comprehensive analysis. One of the most commonly used test batteries for interpreting the characteristics of an injury is the Functional Movement Screen (FMSTM). It makes possible to identify movement limitations and asymmetries which are believed to impact injury risk in sports. The aim of this study is to use the FMSTM to determine whether an eight-week training protocol can predict and prevent injuries in handball. The study sample comprised the fifteen members of the Borac handball club youth team. The initial measurement showed that most players (80%) had an overall score in the test battery ranging from 15 to 20 points. In addition, three players were found to have asymmetry. Only one of the three players had an overall score in the FMSTM of ≤ 14 . The participants scored the lowest in the initial measurement for Rotary Stability, followed by Deep Squat and Hurdle Step Left. They scored the highest in the Shoulder Mobility. After the implementation of the exercise protocol for improving body mobility and stability, the final measurements showed that all the participants had an overall score in the FMSTM of > 14 . The value of eta squared showed that training in between the two measurements had a significant impact. At the time of testing and protocol implementation no players sustained any injuries during matches or in training. This study confirmed that the FMSTM can be used to predict injuries in sports.

Keywords: Final Measurement, Functional Movement Screen, Injury, Initial Measurement, Mobility, Young Athletes



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1. Introduction

Modern training technology has become an integral part of the daily routines set by conditioning coaches. A goal of both coaches and athletes is to improve physical abilities to achieve top results in sports. On one hand, the coach attempts to develop a high level of anaerobic and aerobic abilities, i.e. motor

capacity, and on the other they have to make sure the athletes recuperate, to prevent injuries and to ensure proper movement performance. On that note, special attention needs to be paid to injury prevention, i.e. focusing experts on the improvement of the movement pattern itself [1-3].

Identifying risk of sports injuries and implementing appropriate preventive measures may help conditioning coaches reduce the occurrence of injuries, improve the athletes' performance in competitions, and minimize costs of healthcare for their players [4]. Prospective studies have identified several internal factors which increase the risk of sport injuries, including prior injuries, ligament laxity, limited movement range, low level of aerobic fitness or muscular strength, poor balance and lower level of prior physical activity or training [5-9]. Even though these factors are often studied separately, it is likely that there are multiple factors in the risk of injury. Sports medicine researchers need to determine how an athlete performs specific movement patterns in a particular sport, because it is believed that improper movement patterns and biomechanical faults often contribute to muscular and skeletal injuries in sports [6, 8, 10-12].

Functional Movement Screen (FMS™) is one of the most commonly used test batteries for interpreting the quality of movements [13-18]. It is a non-invasive, inexpensive, quick, and easily implemented tool to assess multiple functional movement patterns of individuals to identify limitations of movement and asymmetry, which are believed to affect sports injury risk [19-23]. The rest is most commonly applied to athletes, but is also recommended for the general population [24]. Numerous studies explored the ability of FMS™ to serve as an injury prediction tool, but the conclusions of these studies are inconsistent, especially in the athlete population [7, 10-11, 22, 25-26]. Using the receiver operator characteristic (ROC) curve, several authors found that for most individuals, the overall score of ≤14 out of the 21 possible points in the FMS™ represents a risk of injury [22, 25], while in other studies none of the results could predict an injury with any certainty [16, 27]. A potential reason why the FMS™ was unable to predict injuries for specific athletes is that FMS™ determines the total dysfunction of mobility, which can greatly differ from the mechanisms that cause sports injuries [4].

FMS™ comprises a set of seven subtests [11, 17], which make up the functional basis of movement, which in turn allows for the evaluation and ranking of

movements [28]. Each individual test is specific and uses stabilization movements, all of which require the individual to perform common basic movement patterns [28]. Stability and mobility are initial information which serve the coach for planning an adequate program for developing motor and functional capacity, but also for preserving and improving postural capacity. In this context, good mobility entails efficient performance of movements. It implies the interaction of specific body parts, i.e. multiple joints, when performing complex movements. When it comes to stability, it entails the ability to control one's body through strength, coordination, balance and movement quality [29]. There is static stability, which implies maintaining the appropriate body position and balance, and there is dynamic stability, which implies motion and movement control, i.e. the ability to counteract unwanted movements or forces. Looking at the human body, mobility should take place in the ankles, hips, thorax, shoulders and neck, while stability should come from the feet, knees, lumbar region and shoulder blades.

Handball is one of the most popular collective sports in the world, where team members pass the ball using their hands, trying to get it into the goal of the opposing team. This game features high tempo, sudden change of direction, jumps that result in powerful shots, frequent contact among the players, and repetitive injuries to knees and shoulders [30]. Therefore, it requires physical prowess and talent, as well as agility and tactics. According to the Olympic Committee, handball is an Olympic sport with a high risk of injury [31]. Handball players use functional movement patterns, just like other sports. Injuries can only be prevented by employing detailed and comprehensive analysis [32]. The most commonly used method for this analysis is FMS™.

Renan Hideki Higashi et al. (2015) found that the prevalence of injuries in youth handball players in a single season was 53.6% [33]. Further, other studies found that the injury frequency rate among elite male Brazilian handball players was 3.7 per 1000 hours of training and 20.3 per 1000 hours of match time [34] and 3.1 injuries per 1000 hours of training and 40.7 per 1000 hours of match time among female Brazilian players [35]. Again, other authors found that the number of injuries per 1000 hours of play was far larger, ranging from 104.5 [36] to 115.8 [37].

Furthermore, previous studies have shown that handball players have lower overall scores in the FMS™ than football players, which indicates that football

players exhibit better functional movement patterns. The movements of football players were more symmetrical than those of handball players. Handball players had greater asymmetry of internal and external rotation of the shoulder. Results of the FMS™ lead to the assumption that handball players carry a greater risk of injury than football players [38]. The results of the FMS™ did not differ relative to the quality of handball players. In the study of Robert Slodownik *et al.* (2018) the average result of FMS™ of Polish players in the first-tier league was 15.5 ± 1.9 , and in the second-tier league the result was 15.4 ± 2.6 points [39]. Since the results of the previous study were re-evaluated after six months, it was concluded that the FMS™ can be a useful tool to recognize specific adaptations in the shoulder joints of handball players. Also, Amir Letafatkar *et al.* (2014) evaluated the FMS™ results for male and female football, basketball and handball players. The average grade for all athletes was 16.9, but unfortunately the results were not broken down into categories of sport or sex [40].

Considering the fact that findings of previous studies did not consistent in terms of FMS™ as an injury prediction tool in athletes' population, the aim of this study was to use the FMS™ to determine the effects of implementing an eight-week introductory preparatory training protocol on the movement performance quality and body stability, as well as prediction and prevention of injuries among youth handball players of the Borac Banja Luka handball club.

2. Materials and Methods

The participant sample in this study comprised the junior team of the Borac Banja Luka handball club, a total of them ($n = 15$), aged $M = 17.5 \pm 1.0$ years, mean height $M = 187.8 \pm 6.8$ cm (Min = 170.0; Max = 197.0) and body mass at an average of $M = 79.9 \pm 8.3$ kg (Min = 70.0; Max = 95.0). The average Body Mass Index (BMI) of the young handball players was $M = 22.6 \pm 2.0$ (Min = 21.0; Max = 25.8).

The Borac Banja Luka handball club is the most successful handball club of Bosnia and Herzegovina of all time. The club was one of the rare handball clubs that was never relegated from the former first league of Yugoslavia throughout its existence, from 1957 to 1991. Players from Borac won six gold Olympic medals playing for Yugoslavia. The club won the European Champions Cup in the 1975/76 season and the European Handball Federation (EHF) cup in the 1990/1991 season. The club always paid special attention to their work on the youth system. The

current generation of youth handball players in the 2020/2021 season won the Championship of the Republic of Srpska and the Premier League of Bosnia and Herzegovina in their age category. Youth handball players train on a daily basis and at least once a week they play official matches. In addition to the competition for youth categories at the level of the Republic of Srpska and Bosnia Herzegovina, they also compete in the first league of the Republic of Srpska for seniors.

The functionality of the locomotor apparatus of youth players was evaluated using the FMS™ diagnostic test battery, developed by Gray Cook, Lee Burton and Barbara Hoogenboom [20]. This screening simplifies the evaluation of the basic movement patterns [20, 28] in relation to subtests: Deep Squat (DS), Hurdle Step (HS), In-Line Lunge (ILL), Shoulder Mobility (SM), Active Straight Leg Raise (ASLR), Trunk Stability Push – Pp (TSP), and Rotary Stability (RS). Measurement was done for both the initial and the final state. The two measurements were three months apart.

Three attempts were used for each subtest. Bilateral subtests were carried out on both sides, and both the left and the right side were evaluated, which is greatly significant in handball, considering player positions in the team, and the dominance of the left or right hand/foot. If there is a difference in values for the left and right side, the lower result is taken as final for the total sum of points. Once all three attempts are performed in each test, the best score is taken, valued on a scale of 0 to 3 in the following way: 0 = pain reported anywhere in the body; 1 = unable to complete the movement pattern or unable to assume the position to perform the movement; 2 = able to complete the movement but must compensate in some way to perform the fundamental movement; 3 = able to perform the movement correctly without any compensation; in accordance with standard expectations of movements associated with each test [10-11, 41].

There were ~10s breaks between performances within each test, and a one-minute rest between the tests. The overall score of the FMS™ was calculated by adding up the grades from the individual tests.

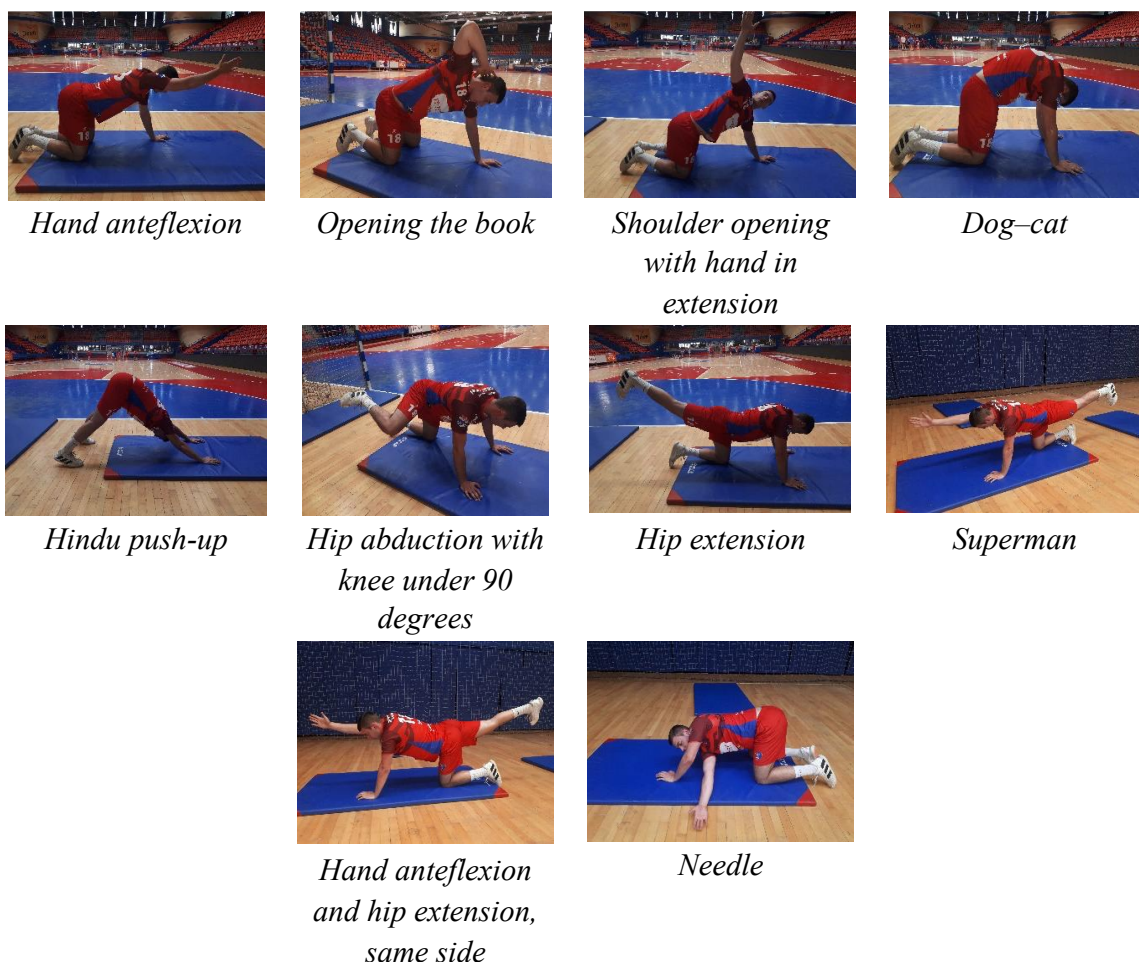


Figure 1 Exercise protocol directed at improving movement mobility.



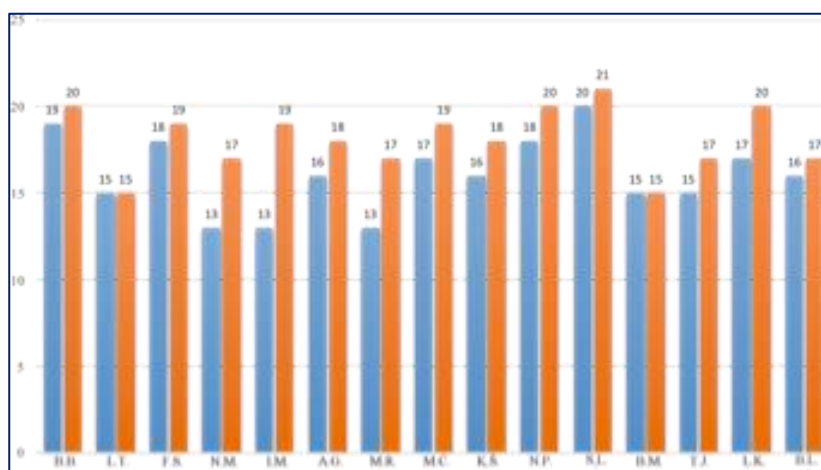
Front plank



Side plank



Back plank

Figure 2 Subprotocol of exercises intended for improving body stability.**Figure 3** Differences in the overall score between the initial and final measurements in the study participants.**Table 1** Paired Samples Statistics and Correlations quality of movement performance and body stability of young handball players

Variable	Measurement	<i>M</i>	<i>SD</i>	<i>SE</i>	<i>r</i>	<i>p</i>
DS	Initial	2.067	0.704	0.182	0.681	0.005
	Final	2.600	0.507	0.131		
HS _{ll}	Initial	2.067	0.594	0.153	0.569	0.027
	Final	2.600	0.507	0.131		
HS _{rl}	Initial	2.133	0.516	0.133	0.491	0.063
	Final	2.600	0.507	0.131		
ILL _{ll}	Initial	2.400	0.507	0.131	0.218	0.435
	Final	2.933	0.258	0.067		
ILL _{rl}	Initial	2.467	0.516	0.133	0.468	0.079
	Final	2.800	0.414	0.107		
SM _{ls}	Initial	2.733	0.458	0.118	0.650	0.009
	Final	2.867	0.352	0.091		
SM _{rs}	Initial	2.800	0.414	0.107	0.535	0.040
	Final	2.933	0.258	0.067		
ASLR _{ll}	Initial	2.467	0.516	0.133	0.764	0.001
	Final	2.600	0.507	0.131		
ASLR _{rl}	Initial	2.533	0.516	0.133	0.645	0.009
	Final	2.733	0.458	0.119		
TSP	Initial	2.600	0.507	0.131	0.739	0.002
	Final	2.733	0.458	0.118		
RS _l	Initial	1.867	0.516	0.133	0.607	0.016
	Final	2.067	0.258	0.067		
RS _r	Initial	2.000	0.655	0.169	0.791	0.000
	Final	2.200	0.414	0.107		

p < 0.05
 Key: DS – Deep Squat; HS_{ll} – Hurdle Step (left leg); HS_{rl} – Hurdle step (right leg); ILL_{ll} – In-line Lunge (left leg); ILL_{rl} – In-line Lunge (right leg); SM_{ls} – Shoulder Mobility (left shoulder); SM_{rs} – Shoulder Mobility (right shoulder); ASLR_{ll} – Active Straight-Leg Raise (left leg); ASLR_{rl} – Active Straight-Leg Raise (right leg); TSP – Trunk Stability Push Up; RS_l – Rotary Stability (left); RS_r – Rotary Stability (right)

Table 2 Paired samples test quality of movement performance and body stability of young handball players

	Paired Differences					<i>t</i>	<i>df</i>	<i>p</i>	ε^2
	<i>M</i>	<i>SD</i>	<i>SE</i>	95% Confidence Interval of the Difference					
				Lower	Upper				
DS	-0.533	0.516	0.133	-0.819	-0.247	-4.000	14	0.001	0.552
HS _{ll}	-0.533	0.516	0.133	-0.819	-0.247	-4.000	14	0.001	0.552
HS _{rl}	-0.467	0.516	0.133	-0.752	-0.181	-3.500	14	0.004	0.485
ILL _{ll}	-0.533	0.516	0.133	-0.819	-0.247	-4.000	14	0.001	0.552
ILL _{rl}	-0.333	0.488	0.126	-0.604	-0.063	-2.646	14	0.019	0.350
SM _{lis}	-0.133	0.352	0.091	-0.328	0.063	-1.468	14	0.164	0.142
SM _{rs}	-0.133	0.352	0.091	-0.328	0.062	-1.468	14	0.164	0.142
ASLR _{ll}	-0.133	0.352	0.091	-0.328	0.062	-1.468	14	0.164	0.142
ASRL _{rl}	-0.200	0.414	0.107	-0.429	0.029	-1.871	14	0.082	0.212
TSP	-0.133	0.352	0.091	-0.328	0.062	-1.468	14	0.164	0.142
RS _l	-0.200	0.414	0.107	-0.429	0.029	-1.871	14	0.082	0.212
RS _r	-0.200	0.414	0.107	-0.429	0.029	-1.871	14	0.082	0.212
<i>p</i> < 0.05									

Each participant could achieve a maximum of 21 points. The reliability of these evaluation protocols was determined with moderate to excellent level of congruence in trained assessors [42-43].

In the competition season, a specific training protocol was implemented (February–April 2021). It comprised two subprotocols which were implemented twice a week, in intervals of 10-15 minutes. The subprotocol of exercises directed at improving mobility of movements comprised 10 exercises (Figure 1), which were carried out in the introductory preparatory segment of the training session, following initial warm-up, in the duration of 30 seconds for each exercise, i.e. for the left and right side.

The subprotocol of exercises intended for *improving body stability* comprised three exercises and four hold positions (Figure 2), which were also carried out in the introductory preparatory segment of the training session, following initial warm-up, in the duration of 45 seconds for each position, two sets each.

The data was statistically processed using the *T*-test of paired samples (repeated measurements), which ascertained whether there was a significant difference between the measured variables in the initial and final state. The amount of the impact of training, i.e. the obtained differences between the final and initial measurements was calculated using the Eta test.

3. Results and Discussion

Figure 3 displays the individual overall score of the initial and final measurements for the study participants. A statistically significant increase of the value of the Total Score from the initial ($M = 16.067$, $SD = 2.154$) to the final measurement ($M = 18.133$, $SD = 1.807$), $t(1) = -4.928$, $p < 0.000$ bidirectionally. The average decrease in the Total Score was 1.799, while the 95% confidence interval was in the range of -2.966 to -1.167. The value of eta squared (2.152) indicates a high impact of the training.

Table 1 displays the score differences in descriptive statistics between the initial and final measurements and the correlative value for each individual test. The Paired Sample Test (Table 2) provided an evaluation of the effects of training on the test score.

- *Deep Squad* score from the initial ($M = 2.067$, $SD = 0.704$) to the final measurement ($M = 2.600$, $SD = 0.507$), $t(14) = -4.000$, $p < 0.001$ bidirectionally. The average decrease in DS was -0.572, while the 95% confidence interval was in the range of -0.819 to -0.247. The value of eta squared was $\varepsilon^2 = 0.552$.
- *Hurdle Step (left leg)* (HS_{ll}) score from the initial ($M = 2.067$, $SD = 0.704$) to the final measurement ($M = 2.600$, $SD = 0.507$), $t(14) = -4.000$, $p < 0.001$ bidirectionally. The average decrease in HS_{ll} was -0.572, while the 95% confidence interval was in the range of -0.819 to -0.247. The value of eta squared was $\varepsilon^2 = 0.552$.

- *Hurdle Step (right leg)* (HS_{ri}) score from the initial ($M = 2.133$, $SD = 0.516$) to the final measurement ($M = 2.600$, $SD = 0.507$), $t(14) = -3.500$, $p < 0.004$ bidirectionally. The average decrease in HS_{ri} was -0.544 , while the 95% confidence interval was in the range of -0.752 to -0.181 . The value of eta squared was $\varepsilon^2 = 0.485$.
- *In-Line Lunge (left leg)* (ILL_{li}) score from the initial ($M = 2.400$, $SD = 0.507$) to the final measurement ($M = 2.933$, $SD = 0.258$), $t(14) = -4.000$, $p < 0.001$ bidirectionally. The average decrease in ILL_{li} was -0.572 , while the 95% confidence interval was in the range of -0.819 to -0.247 . The value of eta squared was $\varepsilon^2 = 0.552$.
- *In-Line Lunge (right leg)* (ILL_{ri}) score from the initial ($M = 2.467$, $SD = 0.516$) to the final measurement ($M = 2.800$, $SD = 0.414$), $t(14) = -2.646$, $p < 0.019$ bidirectionally. The average decrease in ILL_{ri} was -0.541 , while the 95% confidence interval was in the range of -0.604 to -0.063 . The value of eta squared was $\varepsilon^2 = 0.350$.
- *Shoulder Mobility (left shoulder)* (SM_{li}) score from the initial ($M = 2.733$, $SD = 0.458$) to the final measurement ($M = 2.867$, $SD = 0.352$), $t(14) = -1.468$, $p < 0.164$ bidirectionally. The average decrease in SM_{li} was -0.391 , while the 95% confidence interval was in the range of -0.328 to 0.063 . The value of eta squared was $\varepsilon^2 = 0.142$.
- *Shoulder Mobility (right shoulder)* (SM_{ri}) score from the initial ($M = 2.733$, $SD = 0.458$) to the final measurement ($M = 2.800$, $SD = 0.414$), $t(14) = -1.468$, $p < 0.164$ bidirectionally. The average decrease in SM_{ri} was -0.390 , while the 95% confidence interval was in the range of -0.328 to 0.062 . The value of eta squared was $\varepsilon^2 = 0.142$.
- *Active Straight-Leg Raise (left leg)* (ASLR_{li}) score from the initial ($M = 2.467$, $SD = 0.516$) to the final measurement ($M = 2.600$, $SD = 0.507$), $t(14) = -1.468$, $p < 0.164$ bidirectionally. The average decrease in ASLR_{li} was -0.390 , while the 95% confidence interval was in the range of -0.328 to 0.062 . The value of eta squared was $\varepsilon^2 = 0.142$.
- *Trunk Stability Push Up* (TSP) score from the initial ($M = 2.600$, $SD = 0.507$) to the final measurement ($M = 2.733$, $SD = 0.458$), $t(14) = -1.468$, $p < 0.164$ bidirectionally. The average decrease in TSPU was -0.390 , while the 95% confidence interval was in the range of -0.328 to 0.062 . The value of eta squared was $\varepsilon^2 = 0.142$.

The results of the Paired Samples Test did not show a statistically significant increase of value, nor a high impact of training in:

- *Active Straight-Leg Raise (right leg)* (ASLR_{ri}) score from the initial ($M = 2.533$, $SD = 0.516$) to the final measurement ($M = 2.733$, $SD = 0.458$), $t(14) = -1.871$, $p < 0.082$ bidirectionally. The average decrease in ASLR_{ri} was -0.458 , while the 95% confidence interval was in the range of -0.429 to 0.029 . The value of eta squared was $\varepsilon^2 = 0.212$.
- *Rotary Stability (left)* (RS_{li}) score from the initial ($M = 1.867$, $SD = 0.516$) to the final measurement ($M = 2.067$, $SD = 0.258$), $t(14) = -1.871$, $p < 0.082$ bidirectionally. The average decrease in RS_{li} was -0.458 , while the 95% confidence interval was in the range of -0.429 to 0.029 . The value of eta squared was $\varepsilon^2 = 0.212$.
- *Rotary Stability (right)* (RS_{ri}) score from the initial ($M = 2.000$, $SD = 0.655$) to the final measurement ($M = 2.200$, $SD = 0.414$), $t(14) = -1.871$, $p < 0.082$ bidirectionally. The average decrease in RS_{ri} was -0.458 , while the interval of the 95% confidence was in the range of -0.429 to 0.029 . The value of eta squared was $\varepsilon^2 = 0.212$.

The results of the Paired Samples Test did not show a statistically significant increase of value, and the impact of training was borderline moderate and high in:

Handball has one of the highest injury rates among collective sports [44]. Studies have shown that large international handball tournaments have an incidence of 100 injuries per 1000 match hours [36, 44-45]. Injury incidence in young handball players has been reported to be 9.9 per 1000 match hours and 0.9 per 1000 training hours [46], which reduces with age. Young male handball players are at 1.8 greater risk of injury than their female peers [47]. Recent studies have shown that 23% of adolescent handball players in one season have had significant issues with their shoulder joints, half of which reported to have been completely unfit for competitive matches [48].

Most authors researching the matter agree that screening tests can be a tool to predict injuries [49-52]. Screening tests are a necessity in elite handball, especially in adolescent players, due to the high risk of injury [53]. One of the most commonly used movement screening test batteries for predicting risk of injury is the FMS™ [50, 52].

The prospect research, using the FMS™ test battery, first diagnosed the quality of the participants' movements (initial state). Then, an exercise protocol

for improving mobility and an exercise protocol for improving body stability were implemented over three months. The protocols were carried out twice a week in ~10-15-minute intervals. During this period, the players' injuries were recorded. At the end (final state), re-testing was done using the FMS™ test battery.

Analysis of the initial testing (Figure 3) shows that three players, or 20.0% (N. M.; I. M.; and M. B.) have an overall score of ≤ 14 , which indicates an increased risk of injury. Namely, prior studies have found that scores under 14 points in the FMS™ test battery are at 1.5 times [51], 2.7 times [50] and as much as 5 to 10 times higher risk in rugby [54], which, much like handball, carries a high risk of injury. Moreover, studies have shown that players with an overall score in the FMS™ test battery of ≤ 14 points, in addition to getting injured more often, take longer to recover [55]. The remaining 12 players (80.0%) have an overall score in the FMS™ test battery of >15 , which indicates that this generation of young handball players of the RK Borac handball club has a developed quality of movements. Their scores range from 15 to 20 points. Of the three players whose overall score was below 14 points, two play in the pivot position. They are also the only two players whose BMIs indicate *overweight* (N.M. = 25.8; M.B. = 28.1) in relation to the average BMI of the whole team ($M = 22.640$, $SD = 2.042$). Considering their position and activity in offence and defence, and constant contact with opponents, a larger body mass, i.e. an increased BMI is to be expected. Research has confirmed that pivots are voluminous and carry slightly more fat tissue [56-57]. Previous studies have found that there is a negative relation between BMI scores and FMS™ scores in the general population both in children and in adults [23, 58-59] as well as in NFL players, and the relation is especially prominent for lower extremities [60].

Three players (N.M.; B.M.; L.T.) were categorized as "asymmetric", since their ratio of asymmetry exceeded 15%. The 15% limit was chosen because it can increase risk of sport injuries [61].

The participants had the lowest scores in the initial measurement in *Rotary Stability Left* ($M = 1.867$, $SD = 0.516$), and in tests: *Rotary Stability Right* ($M = 2.000$, $SD = 0.665$), *Deep Squat* ($M = 2.067$, $SD = 0.704$) and *Hurdle Step Left* ($M = 2.067$, $SD = 0.594$). The participants had the highest scores in the initial measurements in tests: *Shoulder Mobility*, specifically

Right ($M = 2.800$, $SD = 0.414$) and *Left* ($M = 2.733$, $SD = 0.458$).

The Rotary Stability test evaluates the stability of the pelvis, torso and shoulder blades when performing a movement that involves moving upper and lower extremities. They require coordination, but also kinesthesia of the torso with the upper and lower extremities. When two extremities are lifted off the ground, the most prevalent component of rotation is the one that indicates that the rotation stability test evaluates trunk stability in the transversal plane. Three players exhibited a special deficit (A.G., M.B., K.Š.), and in both tests (Left and Right) they were graded with 1. Based on the characteristics of the game of handball, "the body gains a rotational pattern during the unilateral movement, and the athlete must be able to maintain the stability" (p. 957) [37]. When it comes to young handball players, it is clear from this study that the obtained initial scores in Rotary Stability indicate an insufficient implementation of body stability exercises in the preparatory part of training sessions.

Low scores in the Deep Squat test belong to three players who were graded with 1 (I.M., M.B., L.T.). These three players had an increased risk of knee injury. The reasons of poor execution of the Deep Squat can be traced to poor mobility of the hip joint and the ankle joint, as a result of inadequate implementation of mobility exercises in the introductory part of the training sessions, or in other words, "the flexibility work usually limited to the hamstrings during training makes the athletes more disadvantaged in terms of flexibility of quadriceps and gastrosoleus muscle groups" (p. 957) [37]. Also, one of the players (M.B.) had a hip surgery some time ago. The knee is the most commonly injured body part in handball, and at the same time, knee injuries are the most severe in this sport [62]. Knee injuries are not the most common only in handball players under the age of 14 [63].

When jumping and shooting in handball, the lower extremities are in the air, so their stability heavily depends on their position on the ground [63]. The Hurdle Step test evaluates the ability to perform these movements. In our study, left leg tests have shown that the participants did not have a sufficient level in this test, especially two players (N.M., M.B.). Considering the fact that 80% players are right-handed, meaning that their left leg is dominant in jumping, the engagement of its musculature may contribute to the shortening of the hamstring muscles (m.semitendinosus, m.semimembranosus i m.biceps

femoris), and thus contribute to the decrease in its performance. Flexibility can be preserved and improved with the help of special training programs [64].

The young handball players had the highest scores in subtests Shoulder Mobility Left ($M = 2.733$, $SD = 0.458$) and Right ($M = 2.800$, $SD = 0.414$). The asymmetry rate in this test was low. Most athletes (93%) use both their upper extremities equally. This indicates that these extremities were not subject to injury, which would have caused low values in this FMS™ subtest. In any case, the results of the Shoulder Mobility subtest should be high in sports which primarily require the use of shoulders. Past injuries, improper treatment of the injuries and improper training cause lower scores in this subtest. Handball players employ different types of shots, with their forearm being above or below shoulder level, all the while exposing the shoulder joint to contact and blocks while the arm is extended upwards [65]. The forces exerted on the anatomical structures of the dominant shoulder while taking a shot can exceed the player's body mass 1.5 times [66-67]. This is why shoulder injuries are quite common in handball. The "handball shoulder" is a typical injury pattern that occurs due to excessive use, i.e. a large number of repetitions of shot movements using the dominant hand [68].

Exercise protocols for improving mobility and for improving body stability were then implemented. Their purpose was to improve the mobility of arms, shoulder girdles, thoracic vertebrae, hip and ankle, as well as the stability of the core, or the so-called abdominal ring, which is the basis for good performance of movements, not only in sports, but also in everyday activities. Also, the aim of performing the exercises bilaterally was to neutralize initial disbalance and to improve overall sports abilities.

It should be noted that in the observed period, between the two measurements, there were no player injuries.

After the second (final) measurement, the difference was $\varepsilon^2 = 2.152$, an indicator of impact magnitude for the t -tests. Since the value of eta squared was >0.14 [69], we can conclude that there is a high impact of the applied exercise protocols and that the difference obtained in between the two measurements indicates that there is a high impact of training on the functionality of the locomotor apparatus of young handball players.

When it comes to the scores of individual subtests of the FMS™ test battery in the final measurement, in

Figure 3 we can see that all the players scored >14 . Except for two players who had the same score in the first and second measurements, all the other players scored better in the final than in the initial measurement. These two players had health issues, i.e. problems with their respiratory and cardiovascular systems, and due to medical examinations and required rest, during certain periods of the season they were exempt from training activities or underwent training of lower intensity. Quality of movement was significantly improved in three players whose overall scores in the initial measurement were ≤ 14 . Their BMIs in the second measurement indicated a mild growth ($M = 22.907$, $SD = 2.065$) which is consequential to the increase of muscle mass due to focused daily training activity. Apart from the two pivots, whose BMIs scored as overweight in the initial measurement (N.M. = 26.0; M.B. = 27.8), there is another player with a borderline score (L.B. = 25.2). However, both pivots had significantly better overall scores in the FMS™ test battery, which means that BMI scores do not impact the quality of movements, but that they can be significantly improved through training.

The final scores indicated a high impact of training on the value of the Rotary Stability test (Left and Right), but without any statistical significance. It can be said that the results were expected, since the exercises which were directed at developing stability were carried out in an isometric mode, and as such could not have contributed to any statistically significant increase of dynamic stability, which is dominant in handball.

Results in Table 2 indicate that young handball players had a moderate to high impact of training, but have not displayed a statistically significant increase of the value of the following subtests of the FMS™ test battery: Shoulder Mobility (left and right), Active Straight-Leg Raise (left leg) and Trunk Stability Push Up. A moderate to high improvement in these subtests induced by training activities can also be explained by the fact that the results of these tests were already satisfying already in the initial measurement, so there was no reason to expect that they will improve to the point where they would be statistically significant. Hence, in the Trunk Stability Push Up subtest, nine players (60%) were graded with a 3 in the initial measurement (the rest were graded with a 2), while in the final measurement, two more players joined this group (73%).

Even though the FMS™ test battery was used extensively in the general population of adults, and not used often in the primary and secondary school population, there are a number of papers on the topic [70-72]. Results of recent studies show that 45% of boys aged 12-13 scored 14 or lower in the FMS™ test battery [73]. If we analyze the subtest scores, we can notice visible differences in Shoulder Mobility (Left and Right) and in Active Straight Leg Raise (Right). In these subtests, primary school pupils were in the lower mobility range [73]. Unlike for the general population, for young handball players it was in these tests that they had satisfactorily functional movement patterns.

The FMS™ test battery is attractive for researchers in sports, which is evident by the rising number of published papers on the topic for both recreation players [74] and top-level athletes [75]. Studies are being carried out in all levels both in professional [76] and semi-professional [77] sports, as well as in veteran [78] and adolescent [79] athletes.

When it comes to young athletes, a study in football showed that young football players: Achieved overall scores ranging from 9 to 16 points, where the majority did not have an overall score of ≤ 14 points, almost half the players scored low (i.e. Individual score of < 2) in the Deep Squat subtest, a majority performed poorly in the Trunk Stability Push-Up and Rotary Stability tests, and most of them had asymmetry in at least one of the five subtests [18]. Another study by the author of this paper, on young handball players, showed that they had better scores, because the overall scores increased from the 13-19 range in the initial measurement to the 15-21 range in the final measurement. Only 20% of the handball players had a total score of < 14 in the initial, and none in the final measurement. However, just like in young football players, there were young handball players with low scores in the Rotary Stability subtest.

Engin Dinc *et al.* (2017) pointed out that they achieved success over four weeks of corrective exercises for young professional football players by using resistant rubber and a 65-cm pilates ball, to correct deficiencies in the Deep Squat, In-Line Lunge and Trunk Stability Push-Up subtests, and other subtests as well [80]. Also, Mahsa Jafari *et al.* (2020) following their study on combat sports, concluded that "using [their] proposed training protocol, low FMS scores could be improved to 14 and higher" (p. 102) [81]. All this corroborates the results of this study, which indicate that the implemented exercises protocol over a specific period of time can improve the scores in

the FMS™ test battery overall, as well as in the individual subtests.

Prior research often discussed [25] whether some tests are more valid than others in terms of injury predictability. For example, in a study involving 31 players from youth handball teams from Bundesliga clubs, four players had contact injuries, and four had non-contact injuries. The FMS™ test battery scores did not show any difference between the injured and uninjured players. The same was true for the Front and Square Hop Tests, while there was a difference in the Y-balance Test and the Side Hop test. The authors of that study concluded that these two tests are especially suited for handball players [82]. Still, most other studies claim that athletes with dysfunctional fundamental movement patterns determined using the FMS™ test battery have a higher chance of injury than those with high scores [22].

A drawback of this study is certainly the small participants sample ($n = 15$). But in literature, at least when this matter is concerned, there are quite a few studies done on a sample smaller than 30 participants. In any case, the study was done on a homogeneous, specific and high quality group of one team, which is limited to such a number of players. This is particularly important because of the intervention through an exercise protocol which was conducted uniformly.

5. Conclusion

Consequently, it can be concluded that the implemented eight-week specific protocol improved the functionality of the locomotor apparatus of young handball players. This is best evidenced by the fact that none of the players was injured during match time or training for the duration of the season in which the protocols were implemented, regardless of the scope and intensity of daily training sessions and focused match playing in all three competitions. It is certain that the FMSTM test battery is a significant pre-season tool for evaluating movement quality. Because of the large amount of information provided by the FMSTM, primarily on body posture, torso mobility and stability, and the asymmetry of specific body parts, this method surely deserves its place in working with athletes. In accordance with the obtained study results, exercise protocols for improving mobility and body stability are recommended to coaches, to be used in their daily work with athletes, especially in the preparatory period.

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