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Differences in landing and balance deficits at the ankle joint on stable and unstable surfaces in inflexible and flexible handball players

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ABSTRACT: A flexible ankle joint is suggested to be a contributing factor for sport performance, body control. The purpose of the present study was to investigate the differences in proprioception in static and dynamic movements between subjects with good ankle joint mobility (FL) and poor ankle joint mobility (IN) in male adolescent handball players. The dorsiflexion and plantarflexion of the ankle ROM was measured, at knee extension angle of 120°, with a goniometer. 26 male handball players participated (21.1 ± 4 yrs, 80.8 ± 10 kg, 182 ± 7.38 cm). Furthermore, the players fulfilling previously recommended criteria were assigned to the flexible (n = 6) and inflexible (n = 6) groups and executed two test of static and dynamic movement (BESS Test and Star Excursion Balance Test). Results of the T TEST on IMB SPSS 26 revealed a significant ($p < 0.05$) group effect as (FL) group had less errors than (IN) group on BESS test. In addition, the results of the total sum on stable and unstable surface in star excursion test showed significant differences in the directions: anterolateral (7.4), posterolateral (8.6), posteromedial (7.9), medial (10.8) and anterior medial (8.1). In conclusion, there is a correlation between poor ankle joint mobility and poor proprioception, balance control and athletic movements.

KEYWORDS: *ankle stability, ankle joint mobility, BESS test, handball athletes, injury risk, star excursion balance test*

I. INTRODUCTION

Handball is one of the most popular European team sports along with soccer, basketball and volleyball.

Based on previous research it appears that proprioceptive and neuromuscular abilities have a significant impact on injuries in handball with further research being considered necessary, especially in a contact sport such as handball [1].

Sports injuries of the ankle joint, but also of other joints, such as the knee and shoulder, tend to cause chronic complications in proprioceptive and neuromuscular functions, created by partial or total destruction of the ligament.

Functional weaknesses of the joint, such as reduced maximum strength, poor body posture, but also reduced reaction time are responsible for these injuries which, with proper prevention and informing the injured person of the cause, can be avoided or greatly reduced if used the appropriate warm-up protocol before their activity, which is why further research is considered necessary [2]. Sports sprains, apart from being very common, have a recurrence rate close to 70%, creating symptoms that cause ligament laxity, decreased proprioception, decreased ankle joint muscle function, delayed muscle reaction and stabilization time and with the combination of these neuromuscular features cause mechanical and functional instability in the injured joint [3], [4].

The most common injury in a sports activity is that of the ankle joint, with injuries in this area reaching 60% of the general total. According to the National Collegiate Athletic Association, ankle sprains are most common in men and women who play team sports that require jumping or pivoting and landing, such as basketball, volleyball, soccer and handball [5]. Regarding the cause, it was reported for Volleyball that blockers had the most sprains from stepping on the attacker's foot that crossed the midline [6]. The cost of rehabilitation and treatment for these types of injuries has been reported to exceed $2 billion annually [7]. These sports when played at a high level create high metabolic and musculoskeletal loads on the players due to the repeated maximal efforts. Speeds, jumps and changes of direction burden the athlete's body resulting in injuries [8]. Balance is defined as the ability to maintain the body's center of gravity within the support base and is divided into static and dynamic [9],[10]. Static balance is the ability to maintain the center of mass on a static base of support, such as maintaining balance in a quiet position. While dynamic balance is the ability to maintain the center of mass when the base of support moves or an additional force is applied to the body [11]. In addition, Proprioception is the sense of body movement, the sense of awareness of muscles and the perception of their functions by the individual and in general the knowledge of where and how our body is in space and how it moves in it and it is a neurologic process, while balance is the ability to remain in an upright position [12].

According to Ross et al.[1] who used 17 healthy subjects and 17 with functional instability in the ankle joint, without vision during the execution of the exercise. The subjects performed a one-leg balance exercise, trying to stand as still as possible for 20 seconds. Balance was assessed by measuring the speed of change of the center of pressure, but also how many times they lost their balance (error score), concluding that a multivariate one-leg balance test is a suitable test to predict balance deficits in healthy and with instability in the ankle joint.

The Balance Error Scoring System provides a portable, cost-effective, and objective method of assessing static postural stability on stable and unstable surface which will create a more challenging balance task, which varies by bodyweight. Also, the star excursion balance test is reliable, responsive and clinically relevant functional assessment of lower limbs dynamic postural control [14].

1.1. Purpose of the study

The purpose of this study was to investigate the differences between two groups flexible (FL) and inflexible (IN) for proprioception and balance deficits that may exist on a stable and unstable surface. For the needs of the research, handball male athletes who play in the first division of Italy were used and were divided into two groups inflexible (IN) and flexible (FL) in the area of the ankle.

II. MATERIALS AND METHODS

a. Design of the study

For the examination of the hypotheses of the study, the experimental procedure was conducted in one testing session. At first, the ankle range of motion (ROM) at knee extension angle of 120° was measured for both legs and all the participants completed the questionnaire (Experiment 1). Afterwards, the participants that fulfilled previously recommended criteria were assigned to groups with good ("flexible"), medium and poor ("inflexible") ankle range of motion.

b. Experiment 1: Ankle Range of Motion

Participants: 26 participants (n=26) male post-pubertal handball players (21.1 ± 4 yrs, 80.8 ± 10 kg, 182 ± 7.38 m), active players of the Italian championship, participated in the study. All participants were identified as adolescents (Stage V) according to the growth assessment technique described by [15].

The inclusion criteria were that the participants had to be active players, with no injury in the last three months, never had a concussion, didn't have vertigo the last six months and that they have no vision difficulties. The tests were performed before training sessions, after the procedure being approved from the Institutional Research Committee.

Experimental procedure: The participants completed a questionnaire and their weight, height, age, leg length were measured before the tests. The measurement of ankle ROM was conducted with goniometer that measured the active dorsiflexion and plantarflexion of every participant with the knee in 120 degrees bended. The participants executed the ankle ROM test barefooted in both legs, three times in each leg. During the procedure the participants sat, with their torso in an upright position, on an examination bed. The knee joint was at the edge of the bed, allowing the ankle joint to swing freely. Then, the participants were fixed on the bed and were asked to plantar flex at their maximum capability the ankle joint. The same procedure was repeated with a dorsiflexion. They repeated the procedure three times in each leg. These assessments comprised the active flexibility measures. The participants did not perform any kind of warm-up.

Analysis of variance T Test was performed on IBM SPSS statistics 26. Means, Medians and Standard Deviations was performed, to detect differences in each group. Statistical significant was accepted at $p \leq 0.05$.

Descriptive statistics for the examined parameters are presented as mean ± standard deviation. T test was conducted to see the differences between the groups, flexible (FL) and inflexible (IN). All statistical analysis

[1] [13]

was conducted using the IBM SPSS Statistics 26 software (international business Machines corp., Armonk, NY, USA), with a level of significance set at p=0.05.

c. Experiment 2: Bess Test

Participants: After the completion of Experiment 1, the participants that fulfilled the criteria and that had poor or good ankle mobility set in previous studies were assigned to the flexible (FL) and inflexible (IN) groups. The inclusion criterion for the IN group was the ankle range of motion to be less than 59.8_when _knee was 120°_. The respective criterion for FL was that ankle range of motion to be higher than 71.8_. These criteria were adopted on the basis of past research findings in a large cohort of physical education students, where the frequency distribution analysis identified the previously mentioned values to indicate individuals as “flexible” (7.5th percentile) and “inflexible” (92.5th percentile), respectively [16].

Participants performed for the Bess test, six sets of twenty seconds duration for each set (double leg stance, single leg stance, tandem stance and double leg stance foam, single leg stance foam, tandem stance foam), while the evaluator was counting how many mistakes the participant commits. The dominant leg was always used. The hands should be in the waist all the time and the eyes during the exercises closed. Any movement, imbalance or eyes opened were considered an error. All exercises were performed barefooted and a minimum of a 20 s resting period was allowed between trials to avoid fatigue.

For the calculation of the star excursion balance test (SEBT), Limb length was measured from the anterior superior iliac spine to the most distal aspect of the ipsilateral medial malleolus in supine lying. All reach distances were normalized as a percentage of the stance limb length using the formula [% = (excursion distance/LL) × 100].

Descriptive statistics for the examined parameters are presented as mean _ standard deviation. The best values were collected for each test. Means and standard deviations were calculated, an Independent Samples T-test was run to check the differences between the two groups FL, IN. All statistical analyses were conducted using the IBM SPSS Statistics 26 software (International Business Machines Corp., Armonk, NY, USA), with the level of significance set at a = 0.05 [9],[14].

d. Experiment 3: Star Excursion Test

Participants: After the completion of Experiment 1, the participants that fulfilled the criteria set in previous studies were assigned to the flexible (FL) and inflexible (IN) group. The inclusion criterion for the IN group was the ankle range of motion to be less than 59.8_when _knee was 120°_. The respective criterion for FL was that ankle range of motion to be higher than 71.8_. These criteria were adopted on the basis of past research findings in a large cohort of physical education students, where the frequency distribution analysis identified the previously mentioned values to indicate individuals as “flexible” (7.5th percentile) and “inflexible” (92.5th percentile), respectively [16].

Participants(FL) and (IN) performed for SEBT three tries for each direction (anterior, anteriormedial, medial, posteromedial, posterior, posterolateral, lateral, anterolateral) in each leg and repeated it in unstable surface (foam). The exercise was performed barefooted and a minimum of a 20s resting period was allowed between trials to avoid fatigue. The instructions given were always to have the hands on the waist, be on balance during the exercise and give maximum effort.

Descriptive statistics for the examined parameters are presented as mean _ standard
deviation. The best values were collected for each test. Means and standard deviations were calculated, an Independent Samples T-test was run to check the differences between the two groups FL, IN. All statistical analyses were conducted using the IBM SPSS Statistics 26 software (International Business Machines Corp., Armonk, NY, USA), with the level of significance set at a = 0.05.

III. RESULTS, FIGURES AND TABLES

a. Experiment 1: Ankle Range of Motion

The results of the measurements of the ankle ROM are presented in *Table 1.*

Table 1

	Flexible Mean±SD	Inflexible Mean±SD
ROM (knee = 120°)	77,0±2,1	57 ±2

b. Experiment 2: Bess Test

Based on the outcome of Experiment 1, 6 participants with ankle joint mobility less than 59.8_ formed group IN and 6 participants with ankle joint mobility over 71.8° formed group FL [16].
The results for their BESS test total results are presented in *Table 2***.**

Table 2

BESS TEST MEAN	DOUBLE LEG STANCE	SINGLE LEG STANCE	TANDEM STANCE	DOUBLE LEG STANCE FOAM	SINGLE LEG STANCE FOAM	TANDEM STANCE FOAM	TOTAL
IN	0	2,3	0,3	0	4,2	2	8.83 ± 5.8
FL	0	1	0,3	0	4,3	1,3	7 ± 2

c. Experiment 3: Star Excursion Test
Based on the outcome of Experiment 1, 6 participants with ankle joint mobility less than 59.8_ formed group IN and 6 participants with ankle joint mobility over 71.8° formed group FL [16].
The total SUM on stable and unstable surface for the SEBT are presented in % in *Fig.1*.

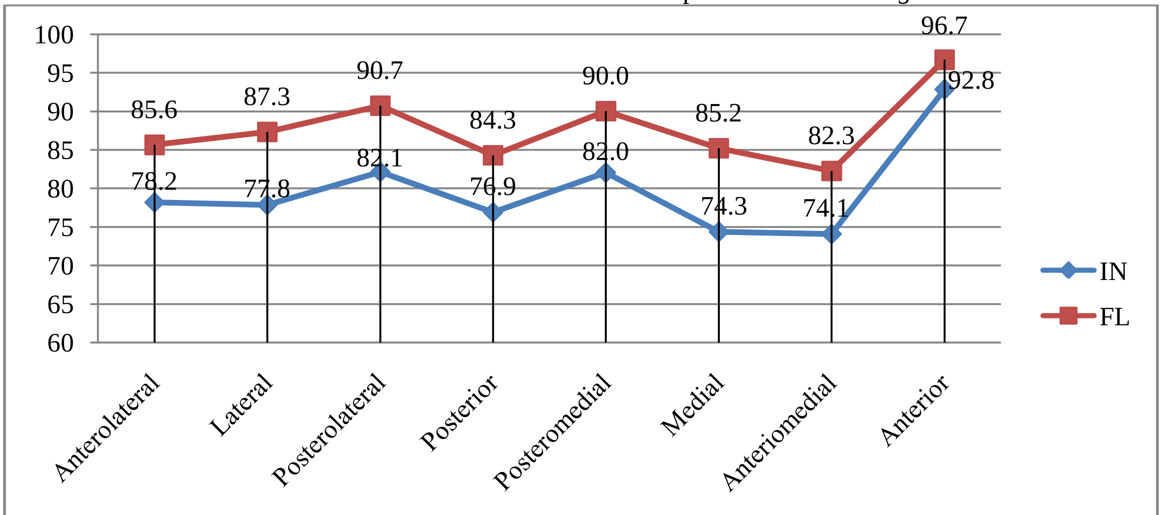

Figure 1

The total SUM on unstable surface for the SEBT are presented in % in *Fig.2***.**

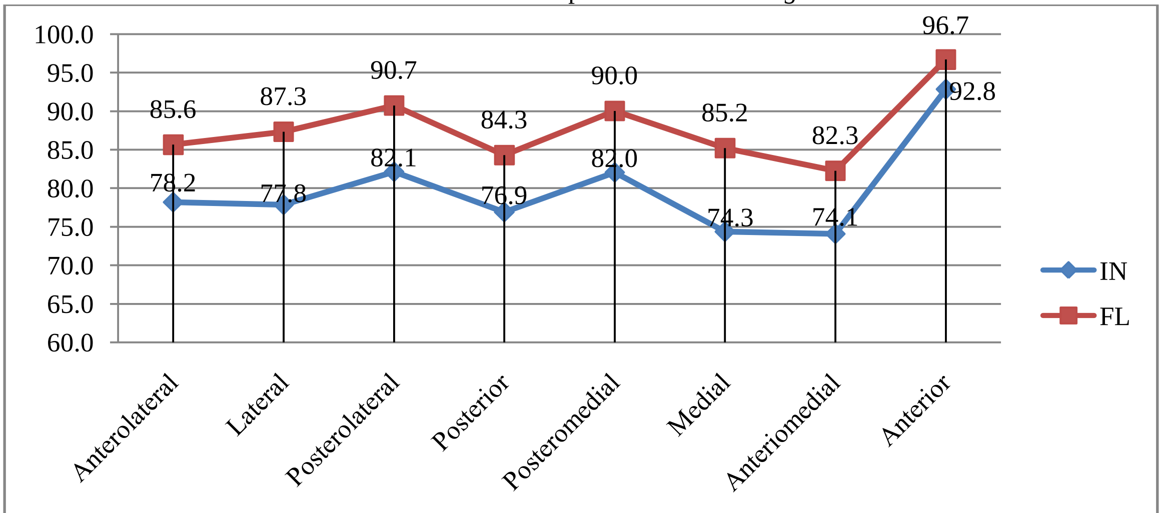

Figure 2

The total SUM on stable surface for the SEBT are presented in % in *Fig.3***.**

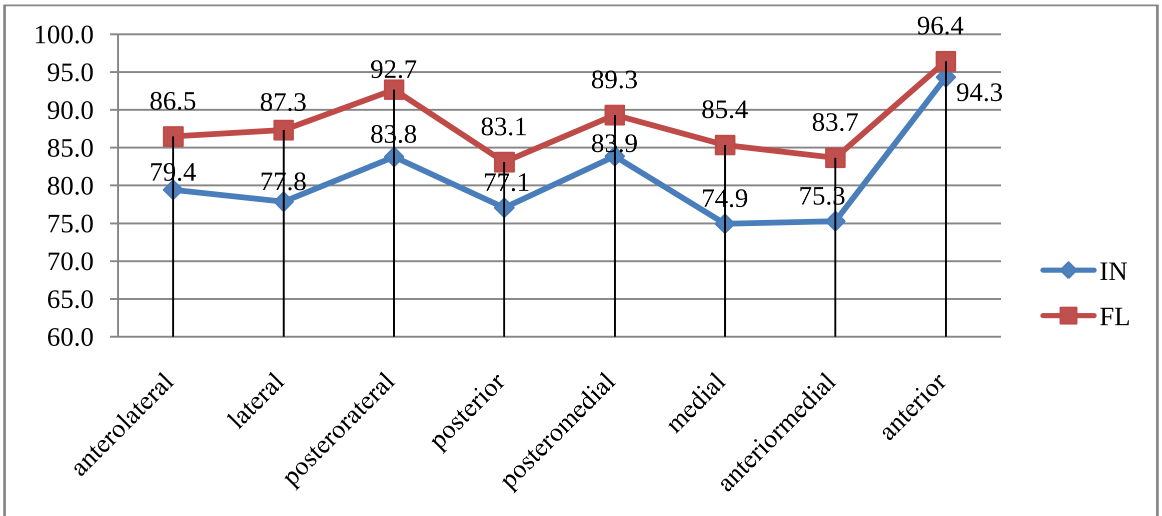

Figure 3

The mean of each leg separately, on stable surface for the SEBT are presented in % in *Fig.4***.**

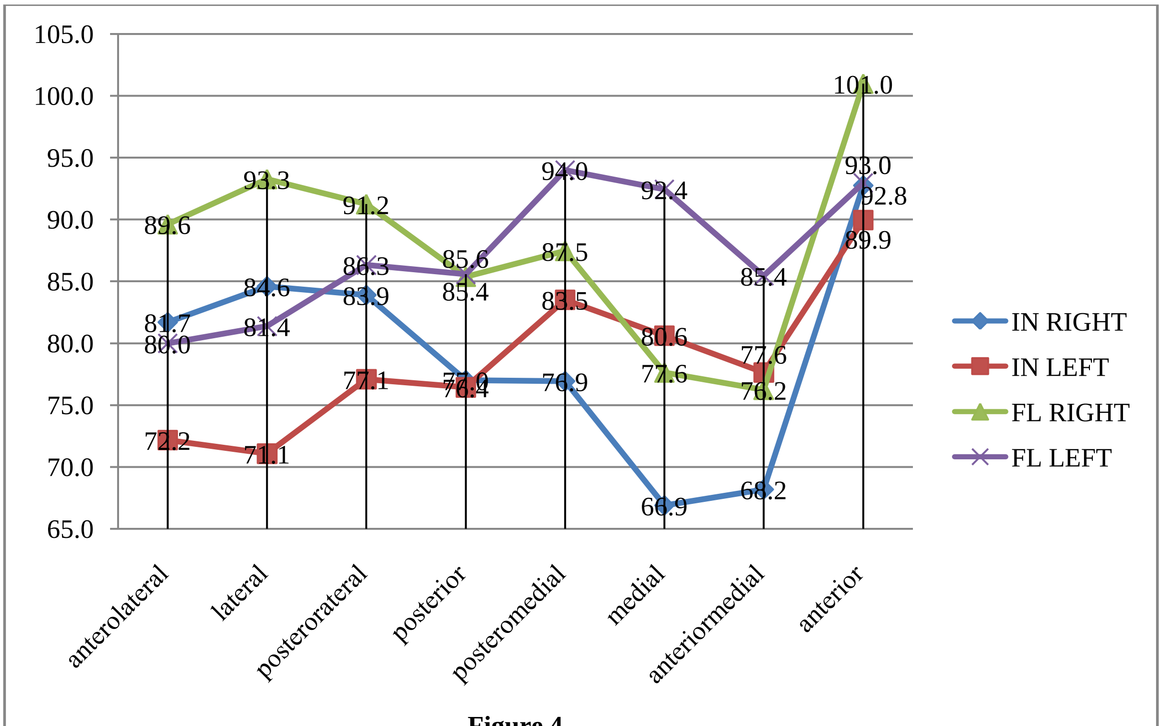

Figure 4

The mean of each leg separately, on unstable surface for the SEBT are presented in % in *Fig.5*.

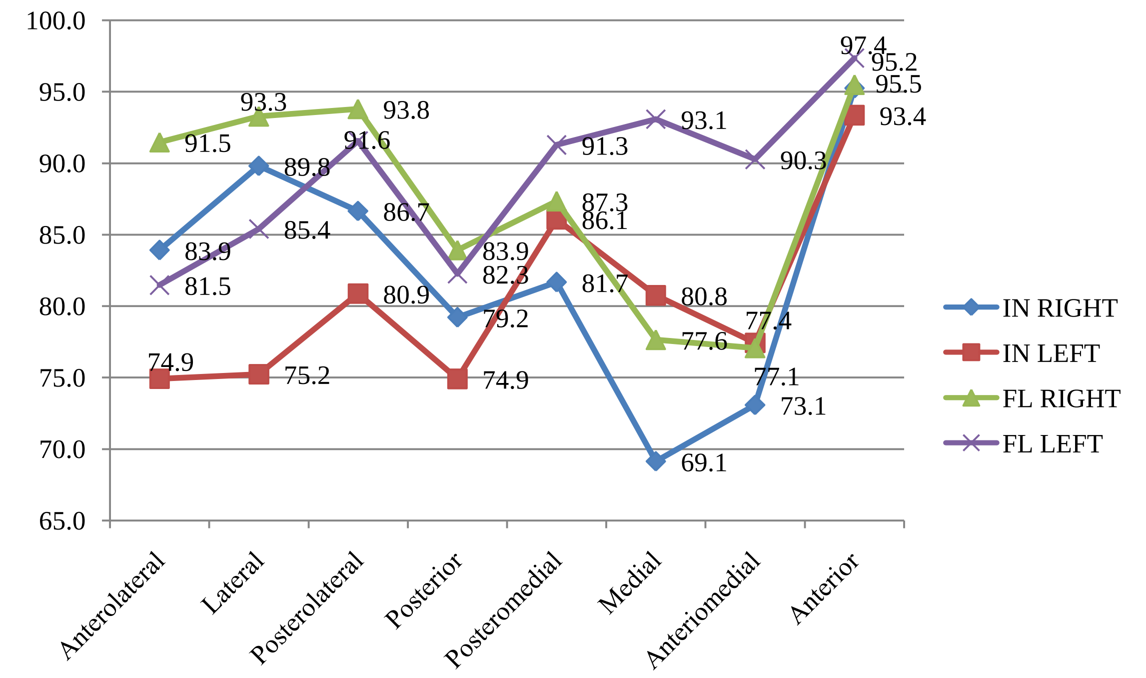

Figure 5

IV. DISCUSSION

The purpose of this study was to examine if active ankle joint mobility (AJM) correlates with significant deficit in proprioception and balance control and consequently in higher risks of injuries in professional handball players.

This topic is of great interest considering the key role played by ankle mobility for the quality of movement, performance, and injury prevention in sports [17], [18], [19].

Studies showed that sports specific practice causes reduction in (AJM) in male athletes which can have possible negative consequences in the structural integrity of the ankle as well as increasing the risk of injuries in players [20].

This analysis supports the theory that there is a correlation between a poor ankle joint mobility (AJM) and weak proprioception and also limited (AJM) leads to deficit in dynamic postural control. One study demonstrated that the rate of ACL ruptures was reduced after introducing proprioceptive training on unstable surfaces to male athletes [21].

The mean ankle range of motion of the 26 participants was 66.1 ± 7.84 with six of them being above the average norms of (AJM) and six participants below the average norms of (AJM). Injury rates reductions and better balance control with higher (AJM) on professional athletes after the application of balance exercise or a stretching program, have been recorded by many authors.

The results of BESS test showed that in double leg stance on stable and unstable surface both groups had zero mistakes.

In single leg stance exercise on stable surface the (IN) group averaged 2.3 mistakes and the (FL) group 1 mistake. In tandem stance exercise on stable surface both groups averaged 0.3 mistakes. In addition, in the single leg stance with foam both groups were really close with the (IN) group committing on average 4.2 and the (FL) group 4.3 errors. Finally in tandem stance with foam exercise (IN) group had 2 mistakes with (FL) committing 1.3. In total there was a significant difference in mistakes with (IN) group 8.83 ± 5.8 and (FL) 7 ± 2.

Findings indicated that the *Star Excursion Balance Test and BESS test* can be used to assess motor control based on its excellent psychometric properties [22]. The results of star excursion test on stable surface in left leg between FL and IN (Fig. 4) showed statistically significant differences on anterolateral (7.8), posterolateral (9.2), posteromedial (10.4), medial (11.8), anterior medial (7.8) and anterior (3) movements but on the left leg on unstable surface (Fig. 5) significant differences were on the lateral (10.1), posterolateral (10.6), medial (12.3) and anterior medial (12.8) movements. The results of the right leg on stable surface (Fig. 4) showed statistically significant differences between the groups in the directions anterolateral (7.9), lateral (8.6), posterior (3,2), posteromedial (10.5), anterior medial (8), anterior (2.5). On the other hand, on unstable surface (Fig. 5) the right leg showed significant statistical differences between the groups on anterolateral (7.5) and posterolateral (7.1) movements.

The SUM of both legs on unstable surface (Fig. 2) showed statistically significant differences between FL and IN on posterolateral (8.9) movement. On stable surface (Fig. 3) the results were different with the anterior (5.6), anterior medial (7.9), medial (11.2), posteromedial (10.5), posterior (8.7) posterolateral (8.2), anterolateral (7.8) showing statistical significantly differences in those movements with the exception of lateral movement. The SUM of both legs on unstable and stable surface (table 3) showed significant differences between the groups in the directions: anterolateral (7.4), posterolateral (8.6), posteromedial (7.9), medial (10.8) and anterior medial (8.1).

The present study showed that there are significant differences between the flexible (FL) and inflexible (IN) group in BESS test and star excursion balance test (sebt).

So, the hypotheses of the study were partly confirmed. In BESS the (IN) group had significantly more errors than (FL) and in Star excursion balance test in the total SUM (Fig. 1) the differences were significant in the directions: anterolateral, posterolateral, posteromedial, medial and anteriormedial with the (FL) group having the better results. In posterior and lateral movement no significant results were observed between these two groups.

The strengths of this study include having a standard protocol that each participant will follow for completing both measures. This data is also more applicable to athletes since proper (AJM) is necessary for proper landing mechanics.

Despite this study adding relevant knowledge to the field and having strengths, limitations still exist. All participants in this study were semi-professional athletes, and the results should be considered when applying to professional athletes or general population due to the difference in physical fitness levels. Secondly the sample size was small and limited to a specific group of people (male adolescent athletes). A third limitation for this study is that while participants can not currently be recovering from an injury, injury history is not being controlled for a long period of time, which could impact dynamic balance abilities, especially any previous ankle injury. Furthermore, the foam surface that was used for unstable surface does not simulate real conditions during the game and the increased contact area between the foot and foam has also been theorized to increase the tactile sense of the foot, also helping to increase postural stability [23].

In future studies, these limitations could be controlled to refine the relationship between (AJM) and dynamic balance.

Nevertheless, the results of the study demonstrated that individuals with greater (AJM) can utilize more efficiently space during a physical activity and have better proprioception in dynamic and passive movements.

V. CONCLUSIONS

Based on the findings of the present research, it could be proposed that the poor (AJM) can correlate with the poor proprioception, poor body control and reduction of athletic capacity, in specific moving directions on stable and unstable surfaces.

Thus, mobility tests should be implemented regularly before training sessions. In addition, the training programs should aim to improve the (AJM), for the enhancement of the player's performance, the improvement of body control and reduction of the risk of injuries.

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Institutional Review Board Statement: The study was conducted according to the guidelines of the declaration of Helsinki and approved by the research committee of Democritus University of Komotini.
Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.
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