CONSEQUENCES OF ANKLE SPRAIN ON JOINT INSTABILITY AND REACTION TIME IN HANDBALL PLAYERS

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Abstract. *In handball, ankle sprains represent 20% of all injuries and are more common than hand or shoulder injuries. Ligament and soft-structure lesions arising from an ankle sprain involve the aforementioned peripheral receptors and lead to a decrease in the quality of peripheral feedback provided to the central nervous system, which influences the muscle reaction time. Depending on the severity of the sprain, the recovery period ranges between two and four weeks, sometimes being even longer. The literature presents the multiple consequences of ankle sprains on the athletes' functional abilities, for instance: a decrease in muscle strength and endurance, an increase in the activation time of antagonist muscles, the occurrence of chronic joint instability, the early onset of osteoarthritic processes, which leads a decline in sports performance. The present paper was carried out on 17 handball players aged between 15 and 16 years and aimed to highlight the existence or nonexistence of correlations between the variables represented by: number of ankle sprains, position on the field, degree of joint instability, muscle reaction time, level of pain. Following the analysis of the results, the existence of statistically significant direct connections between the analysed variables is demonstrated. The paper provides specialists with an overview of the functional consequences of ankle sprain, which can have an influence on the results achieved in sports performance.*

Keywords: *handball, ankle sprain, reaction time.*

Introduction

Ankle sprain is one of the most common musculoskeletal injuries encountered in handball and professional sport. It is believed that the production mechanism of an ankle sprain is mainly based on inversion and that ankle sprains rarely occur by eversion (Chui-Wai Ha et al., 2015). Depending on the severity of the sprain, the recovery period ranges between two and four weeks, sometimes being even longer. The literature presents the multiple negative consequences of ankle sprains on the athletes' functional abilities, for instance: a decrease in muscle strength and endurance, an increase in the activation time of antagonist muscles, the occurrence of chronic joint instability, the early onset of osteoarthritic processes (Witchalls et al., 2011), which leads a decline in sports performance.

Increased reaction time, inhibition of the antagonist muscle together with functional instability that occurs during sports activities are some of the most common negative consequences of ankle sprains following acute injury (Sheth et al., 1997). Reaction time depends on the ability of the central nervous system to process as quickly as possible the stimuli received from peripheral sensory receptors. At the body level, the information takes the following pathway: (external or internal) stimulus -» sensory neuron -» spinal cord/brain -» motor neuron -» muscle and practical or verbal response. After overcoming the acute phase of ankle sprain, athletes suffering from joint instability (in the absence of major ligament injuries that generate significant biomechanical deficits) show an impairment of the somatosensory pathway, which results in a decreased number of sensory afferents sent from the ankle joint to the central nervous system (Denyer et al., 2013). These mechanisms have as a consequence a decrease in motor control, which leads to a recurrence of the ankle sprain or the occurrence of new injuries (Borghuis et al., 2008). After an ankle sprain, reaction time can increase in duration because of pain or ligament lesions (affecting the proprioceptive system). The presence of pain leads to the activation of corresponding nociceptors that are measured by decreasing the amplitude of the electromyographic signal and the force of contraction, which is directly proportional to the intensity of the pain. Ervilha et al. (2005) have noted that, when there is soreness, there is a decrease in electromyographic signals for both antagonist and synergistic muscles. Reaction time can be assessed through the visual, auditory, tactile and other analysers.

Although an individual assessment of these analysers is achieved in everyday life, the central nervous system makes an association of all the sensory information received from all peripheral receptors, integrates them and provides a motor response. The rationale described above is attributed to generalised muscle inhibition that, together with the impairment of the sensory ligament system, are two ideal preconditions for the occurrence of a new injury.

Proprioceptive training is one of the few ways to improve the values of reaction time, the degree of antagonist coactivation and ultimately the functional abilities of the ankle joint.

In conclusion, ankle sprain is a common musculoskeletal disorder that is not treated with sufficient attention by athletes and coaches, in most cases. Incomplete treatment of an ankle sprain generates multiple functional consequences that will be analysed in this research.

The *purpose* of this paper is to identify the connection between ankle sprain pain, reaction time and antagonist coactivation time in athletes who have experienced one or more ankle sprains.

The *objectives* of the research are: to perform an objective assessment of participants in order to determine the values of reaction time, functional joint instability and antagonist coactivation time; to establish correlations between the measured parameters and the sports activity performed by athletes.

The research *hypothesis* assumes that, in athletes who have experienced one or more ankle sprains, there is a direct connection between reaction time, functional joint instability, pain level and coactivation time of the antagonist muscle.

Methodology

Methods

The methods used in this research are: theoretical documentation, measurement and assessment, observation, data recording, data analysis and interpretation, graphical method.

Participants

The research took place in the Sports Hall of the "Ștefan Cel Mare" National Pedagogical College in Bacău, and the participants were 17 handball players (average age: 16.2 years, average height: 184.76 cm, average weight: 75.29 kg) (Table 1).

Table 1. *Player identification data*

Player	H	W	A	TF	POF	TG
1. DA	186	68	17	Left	Centre backcourt	43
2. TT	190	70	16	Left	Left backcourt	97
3. AR	177	78	17	Left	Right backcourt	32
4. IE	168	80	17	Right	Pivot	1 5
5. BV	185	77	17	Left	Centre backcourt	2 0
6. AA	175	65	16	Left	Left winger	59
7. BD	187	75	16	Left	Right backcourt	53
8. MA	182	73	16	Left	Goalkeeper	0
9. CR	180	80	16	Left	Pivot	36
10. GC	199	84	16	Left	Right backcourt	5
11. DG	179	57	16	Left	Left winger	22
12. FD	188	67	16	Right	Right winger	28
13. AS	183	68	16	Left	Left winger	62
14. DD	180	91	16	Left	Pivot	10
15. FR	197	85	16	Left	Left backcourt	31
16. RE	188	84	16	Right	Left winger	1 7
17. PI	197	78	17	Left	Left backcourt	53
AV	184.76	75.29	26.29	-	-	34.29

Legend: H = height, W = weight, A = age, TF = take-off foot, POF = position on the field, TG = total goals, AV = average value

Athletes were assessed as follows:

- reaction time assessment - using the reaction time measurement test (Biopac MP36, L11 - reaction time). The reaction time test was performed with the lower limb for the plantar flexion movement according to the following sequence: 1 - the athlete was in a sitting position with the tested leg above the feedback button; 2 - the headphones were put on the athlete's ears; 3 - the athlete was instructed on the test to be performed; 4 - the device was calibrated and a test was performed; 5 - the actual testing was done; 6 - the recorded data were saved for further analysis and interpretation.

- assessment of the antagonist coactivation time using surface electromyography (Biopac MP36, L1 - electromyography). The test was conducted in parallel with the reaction time test. We cleaned the athlete's skin and positioned the electrodes at the tibial anterior muscles (TA) and triceps sural (TS). Athletes were given the instructions to be followed at the same time with those for the reaction time test. The assessment followed the time period between the initiation of muscle contraction for the plantar flexion movement (TS) and the coactivation of the antagonist muscle (TA). (Figure 1)

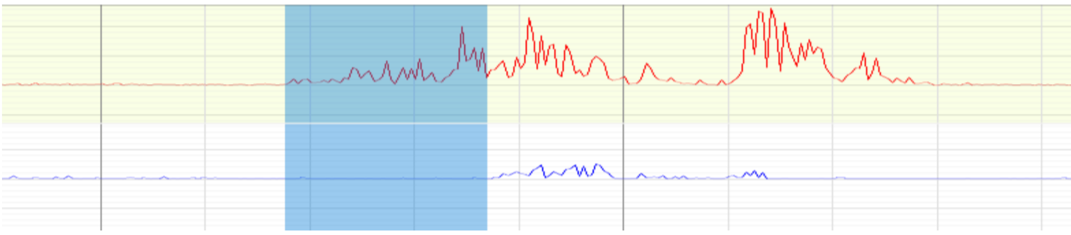

Figure 1. Coactivation of the antagonist muscle

Note. The contraction of the agonist muscle is represented by the red line, and that of the antagonist muscle, by the blue line. The blue highlighting on both graphs represents the coactivation time between agonist and antagonist muscles.

- assessment of the degree of ankle joint instability using the Foot and Ankle Disability Index Questionnaire that has some of the items dedicated to the level of pain (Appendix 1).

Results

The results obtained from player assessment are shown in Table 2. To determine the degree of correlation between mentioned variables, the Pearson correlation test was used (Table 3), and the statistical data were processed using IBM SPSS Statistics, version 20.

Table 2. *Results for reaction time, the degree of joint instability and the level of pain*

Player	NS	RT (ms)	FJI %	P %	ACT
1. D.A.	1	0 . 343	100	100	0.205
2. T.T.	0	0 . 354	100	100	0.230
3. A.R.	1	0 . 325	97	85	0. 354
4. I.E.	0	0 . 280	77	65	0. 416
5. B.V.	0	0 . 340	80	84	0. 315
6. A.A.	0	0 . 283	93	95	0. 217
7. B.D.	0	0 . 283	100	95	0. 230
8. M.A.	0	0 . 302	100	100	0. 236
9. C.R.	3	0 . 388	84	75	0. 415
10. G.C.	0	0 . 330	84	85	0. 364
11. D.G.	4	0 . 354	77	75	0.462
12. F.D.	1	0 . 421	79	75	0. 476
13. A.S.	2	0 . 320	86	85	0. 340
14. D.D.	0	0 . 288	86	100	0. 293
15. F.R.	1	0 . 292	79	65	0. 292
16. R.E.	2	0 . 357	81	75	0. 749
17. P.I.	0	0 . 319	97	85	0. 251
AV	0.88	0.320	88.23	84.94	0.343

Legend: NS = number of sprains, RT = reaction time, ms = milliseconds, FJI = functional joint instability, P = pain, ACT = antagonist coactivation time, AV = average value

Table 3. *Pearson correlation matrix for the measured variables*

	1	2	3	4	5	Mean	SD
1. Sprains	1					0.88	1.21
2. Reaction time	. 510 *	1				0.32	.039
3. Disability index	- . 421	- . 247	1			88.2	9.07
4. Pain	- . 445	- . 223	. 803 **	1		84.9	11.19
5. Coactivation time	. 564 *	. 453	- . 590 *	- . 605 *	1	337.9	139.01

Note: N = 17; * p < .05; ** p < .01; SD = standard deviation

Following the analysis of the results obtained by applying the Pearson correlation matrix (Table 3), correlations were found between some variables:

– a positive correlation between the number of ankle sprains and reaction time: $r(17) = 0 .510$, $p < 0.05$;

– a positive correlation between reaction time and antagonist coactivation time: $r(17) = 0.564$, $p < 0.05$;

– a positive correlation between ankle joint disability index and pain level: $r(17) = 0.803$, $p < 0.01$;

– a negative correlation between ankle joint disability index and antagonist coactivation time: $r(17) = -0.590$, $p < 0.05$;

– a negative correlation between pain and antagonist coactivation time: $r(17) = 0.605$, $p < 0.05$.

Discussion

The analysis of the results (shown in Table 2 and Table 3) allows us to present a series of ideas.

There are positive correlations between the number of ankle sprains and reaction time: $r(17) = 0.510$, $p < 0.05$), as well as between the number of ankle sprains and antagonist coactivation time: $r(17) = -0.590$, $p < 0.05$, which demonstrates the negative influence of an ankle sprain on the motor control system.

Existing research in the literature confirms delays in the reaction time of athletes who have experienced one or more ankle sprains, especially in those suffering from chronic joint instability (Mitchell et al., 2008). The causes of worsening reaction time and antagonistic coactivation can be: muscle fatigue, capsular and ligament injuries, biomechanical deficits, muscle imbalances, damage to the somatosensory system (Hoch & Mckeon, 2014; Kellis et al., 2011).

If we add the reaction time of player 1 - D.A. (0.343 ms) and the antagonist coactivation time (0.205 ms), there is a period of time of 0.543 ms until the occurrence of muscle coactivation. Based on the results obtained by each player, these values range between 0.5 ms and 1 sec. The time during which an ankle sprain by inversion may occur is about 0.062 ms (DeMers et al., 2017). The data presented suggest that the time between ground contact and the onset of muscle contraction is too long to be controlled by the leg muscles. Therefore, in order to prevent ankle sprain, a mechanism is needed for additional protection, which is known as contraction muscle anticipation. It has the role of increasing joint stiffness and sensitivity of the neuromuscular spindles and seems to be more effective in protecting the ankle joint than the reflex response provided by the central nervous system (Martin et al., 2013).

Feger et al. (2015) reported a coactivation time of 0.290 ms of the tibialis anterior muscle in people without chronic joint instability and a time of 0.360 ms in those who had experienced one or more ankle sprains. In the research athletes, antagonist (anterior tibial) muscle coactivation had an average value of 0.343 ms after the initiation of contraction in the triceps sural muscle, and these results are comparable with those reported in the literature. Increased values of the anterior tibial muscle coactivation were recorded by Li et al. (2018) and Monteleone et al. (2014) in people with joint instability. These authors consider that the increased activity of the tibialis anterior muscle is a way to provide ankle joint stability in the medio-lateral direction.

Research on the connection between pain and the motor control system demonstrates the existence of correlations between these variables, in the direction of increasing the risk of injury (Borsook, 2007). In our research, the ankle joint disability index (which indirectly measured the performance of the motor control system) had a strong correlation with the level of pain: $r(17) = 0.803$. $p < 0.01$. Based on the assumption that pain inhibits movement, all participants who experienced a high level of pain had poor results when they tested their ankle joint functionality (I.E. - FJI: 77, pain: 75; D.G. - FJI: 77, pain: 75; F.R. - FJI: 79, pain: 65; R.E. - FJI: 81, pain: 75, etc.).

There are a number of measures that can be taken by athletes to combat the reaction time delays, as well as the lack of muscle coactivation. These are: the use of fixed orthoses, which can improve the extrinsic forces exerted on the ankle joint (Kumar et al., 2020) and the application of proprioceptive exercise programmes for a period of at least six weeks (Osborne et al., 2000). Our research has established the order of performing proprioceptive exercises depending on the support surface used (ground, elastic trampoline, balance disc and air cushion) (Rață et al., 2020) and the positive results obtained on muscle coactivation and joint stability after applying proprioceptive exercises for 15 weeks (Antohe et al., 2021).

All variables recorded in our research reveal an alteration of feedback and feedforward systems (as particularly important mechanisms for injury prevention), which are supported by motor control through the closed-loop control theory (Latash et al., 2010). The positive correlation between reaction time and antagonist coactivation time: $r(17) = 0.564$, $p < 0.05$ demonstrates the direct connection between auditory and proprioceptive analysers (neuromuscular spindles, ligaments, joint capsule) and the importance of these systems in the occurrence of an ankle sprain. Basically, 4 of the 5 athletes (4. I.E., 6. A.A., 7. B.D., 14. D.D. and 15. F.R.) whose reaction time values were lower than 0.300 ms (average value = 0.320) recorded values less than 0.300 ms of the antagonist coactivation time (average value = 340 ms).

Following the analysis of the number of goals scored by each athlete, we found a tendency to increase the number of goals in athletes who recorded very good results for the ankle joint disability index (TT - 100% disability index, 97 goals; DA - 100% disability index, 43 goals; BD - 100% disability index, 53 goals).

It should also be emphasised that the three athletes whose take-off foot is the right one (IE, RB, RE) recorded the lowest time values for the antagonist coactivation (0.416 ms, 0.476 ms, 0.749 ms) and the level of pain (65, 75, 75). Due to the limited number of participants included in the research, we cannot draw a conclusion regarding their laterality and the connection between all assessed parameters, but we think that this topic is open for future research.

Conclusion

Following the research, we have found a very close connection between ankle sprain, the performance of the motor control system and the functional deficits that it generates (reaction time, antagonist coactivation time, disability index, etc.), which is given by the recording of effectively negative values in sport. By analysing the data presented, we have identified the existence of various correlations between all assessed items, which allows us to state that the hypothesis according to which "in athletes who have experienced one or more ankle sprains, there is a direct connection between reaction time, functional joint instability, pain level and coactivation time of the antagonist muscle" is validated.

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Appendix 1. Foot and Ankle Disability Index Questionnaire

ANKLE JOINT STABILITY LEVEL ASSESSMENT QUESTIONNAIRE

Adapted from the Foot and Ankle Disability Index (Fadi) Score and Sports Module Questionnaire

Name and surname:	Assessment date:
Supporting leg:	Position on the field:
Number of sprains suffered in the last year:	Resting period after an ankle sprain:
Treatments received for an ankle sprain (if any):	

1. DYNAMIC STABILITY ASSESSMENT:

Respond to all questions in the table below and try to describe your symptoms as accurately as possible:

0 - impossible to perform 1 - severe difficulty 2 - moderate difficulty
3 - low difficulty 4 - without difficulty

Standing		Abrupt stop	
Walking on normal ground		Contacts during game	
Walking on rough ground		Walking on a slope	
10-minute walking		Changes of direction	
Step climbing		Landing after jumping	
Tiptoe lifting		Running	
Ability to perform your sport without pain			
Ability to perform sports activities without pain limitations			

In order to find out the level of dynamic ankle instability, calculate the arithmetic mean of all responses (1 + 1 + 1/3) and refer to the following values:

0 - very high instability 1 - high instability 2 - medium instability
3 - slight instability 4 - no instability

2. STATIC STABILITY ASSESSMENT:

1 - Standing with your eyes closed on the affected foot, keep your balance for 30 seconds. Time it in your mind and write down the number of seconds spent on the foot:

2 - Standing on the balance board with the affected foot, keep your balance for 30 seconds. Time it in your mind and write down the number of seconds spent on your foot. If you have had any imbalances or have fallen off the board, write their number on the sheet:

3. LEVEL OF PAIN:

Complete the table below with the number corresponding to your pain level.

Pain during sleep	
Pain during training	
Pain level in the morning	
Pain level at rest	
Intermittent pain	

0 - unbearable pain 1 - severe pain 2 - moderate pain
3 - low pain 4 - without pain

In order to find out the level of ankle pain, calculate the arithmetic mean of all responses.