Original Article

The Impact of Training Load on the State of the Vestibular System of Athletes specializing in Hand-to-Hand Combat

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Abstract:

The purpose of the study was to assess the impact of the training load on the static and dynamic stability of athletes specializing in hand-to-hand combat. The study of static and dynamic stability (SDS) was attended by 20 individuals (the first group) who were not involved in sports professionally, 23 athletes (the second group) engaged in hand-to-hand combat with semi contact with an opponent, and 24 athletes (the third group) specializing in hand-to-hand combat with full contact. The average age of all athletes was (21 ± 1.5) years. Registration of SDS indicators was carried out before and after training, corresponding to the athletes' levels of training, using a stabilographic platform. Statistical analysis of the results of the study was performed using the Statistica 6.0 software package and descriptive statistics methods. The clustering of indicators was carried out according to the k-means algorithm; the reliability of pair differences was assessed using the Wilcoxon and Mann-Whitney criteria. To identify homogeneous groups, SDS indicators were clustered according to the k-means algorithm, which allowed us to distinguish two clusters in each group. We included people with high vestibular functions into the first cluster of each group (55-70% of the athletes), the second cluster (30-45%) encompassed athletes with low vestibular function. In the first cluster of each group, training caused an increase in SDS indicators by 20-25%, except for the equilibrium function quality index (EFQ), which decreased by 9-12%. In athletes with low vestibular functions (the second cluster of each group), the training load led to a significantly larger (36-48%) increase in SDS and a decrease in EFQ by 26-35%. Thus, a significantly more pronounced reaction to the training load was detected in individuals with initially lower vestibular functions. The obtained results showed that elite athletes specializing in hand-to-hand combat may have low SDS. As a result of the training load, vestibular functions were significantly reduced in such athletes. This deteriorated the functional state of athletes and could cause poor performance in competitions. There was no significant dependence of the vestibular functions of athletes on the type of hand-to-hand combat.

Keywords: hand-to-hand combat, vestibular functions, stabilography, training load.

Introduction

The vestibular system, along with the visual and somatosensory systems, plays a leading role in maintaining human balance. The equilibrium function is a complex reflex process that is controlled by a continuous stream of impulses coming from the muscles, proprioceptors of tendons, skin exteroceptors, vestibular and visual apparatus to the corresponding sections of the central nervous system. With a loss of equilibrium, these impulses activate reflex contractions of muscle fibers to restore equilibrium. Thus, reflex contractions of the muscles are the cause of continuous body vibrations, which are aimed at maintaining balance (Winter, 1995; Skvortsov, 2007; Gagey, et. al, 2008). These fluctuations are not always visible from the first sight, but can be detected using special biomedical electronic systems. One of the most widely used methods for studying the human vestibular system is stabilometry (statography, posturography). The stabilographic studies record changes in the position of the projection of the center of gravity on the support area (Skvortsov, 2004, 2010; Sliva, 2005).

Various parameters of stabilograms carry information about the state of the musculoskeletal and nervous systems, the inner ear and balance organs, the presence of vertebrospinal pathology, dizziness (Kompaniets, 2001; Van Emmerik et al. 2002; Farnaz et al. 2016; Andreev et al. 2017).

The use of stabilography in sports and sports medicine allows you to timely assess the functional fitness of athletes and adjust training modes, the results of injuries treatment and rehabilitation measures, develop special training exercises and practice weightlifting techniques, optimize the choice of stance for shooters, positions for skaters, gymnasts, cyclists (Winter, 1995; Balter, 2004; Paillard et al. 2015; Williams. 2016; Rannama. 2017). In the course of improving sportsmanship, we observed changes in the amplitudes of body swing and an increase in stability when performing standard and a number of complicated poses of static and dynamic equilibrium (Van Emmerik et al. 2002).

Maintaining the body balance is a dynamic process. The body of a standing person makes sometimes, almost invisible, sometimes clearly visible oscillatory movements in various planes. The characteristics of the oscillations (their amplitude, frequency, direction, as well as the average position in the projection onto the support plane) are sensitive parameters reflecting the state of various systems involved in maintaining the equilibrium position (Gagey et al. 2008; Mikołajec et al. 2017; Kalnysh et al. 2018).

Sports activities require a wide range of spatial-motor orientation, accuracy, speed, stability and versatile coordination of movements in time and space. Preserving the balance of the body and coordination of movements is one of the most important conditions for human life, which allows interacting actively with the environment. The study of the accuracy of human movements is of interest in many areas of life, of particular importance in sports. The method of stabilometry is used in the measurement and evaluation of static and dynamic equilibrium in sports, especially in those types where skills and stability determine the sports result when performing movements of different coordination complexity. It can be clearly seen in sports and rhythmic gymnastics, figure skating, sports acrobatics, jumping in water, freestyle, skiing, martial arts (Shestakov, 2007; Andreev et al. 2017; Santos, 2018).

The ability to maintain balance is an important component of success in many kinds of sport (Fidler et al. 2005; Camliguney et al. 2012; Filingeri et al. 2012; Zech et al. 2015; Güler et al. 2017; de Mello et al. 2017; Rannama et al. 2017; Campos et al. 2018). These kinds of sport include different types of martial arts and hand-to-hand combat, too (Gribble-Grzegorz et al. 2013; Zago et al. 2015; Adamovich et al. 2018; Shtefiuk et al. 2018; Kochina et al. 2019).

Hand-to-hand combat includes various technical and tactical elements and is a complex coordination type of martial arts, the success of which requires athletes possessing appropriate qualities. Performing the technical actions in hand-to-hand combat, which is a synthesis of protective actions of hands and legs with the technique of seizures, painful methods, suffocations and throws, places rather high requirements for the adaptation abilities of an athlete with regard to acyclic manifestations of dynamic and static efforts (Ashkinazi et al. 2006; Dykyi, 2016).

One of the important attributes of hand-to-hand combat training is the static and dynamic stability, which determines the ability to maintain equilibrium in external influences during training sparring and competitions. SDS is determined by the properties of the human vestibular system and its compatible functioning with the visual, proprioceptive and other afferent systems (Pokrovskiy, 2007).

Hand-to-hand combat training requires possession of a wide range of spatial and motor orientation, accuracy, speed, stability, versatile coordination of movements in time and space (Pardaev, 2009; Campos et al. 2018).

With the corresponding innate abilities and during the improvement of sportsmanship, the activity of the vestibular system is improved, which is manifested by the minimization of the amplitudes of oscillations of the body and the improvement of the quality of the SDS. SDS study during the selection for hand-to-hand combat classes allows to choose candidates who have vestibular functions corresponding to this kind of sport. SDS indicators can also be used to assess the suitability of the training load to the individual characteristics of the athlete's body. Significant deterioration of the SDS indicators proves the need for correction of the training system, the presence of athletes in a state of overtraining and stress.

The analysis of modern literature showed that the methods of stabilography are highly informative in norm, in pathology, in the dynamics of sports training and various activities.

The purpose of the study was to assess the impact of the training load on the static and dynamic stability of athletes specializing in hand-to-hand combat.

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Methods

Participants

The study of static and dynamic stability (SDS) was attended by 20 individuals (the first group) who were not involved in sports professionally, 23 athletes (the second group) engaged in hand-to-hand combat with semi contact with an opponent, and 24 athletes (the third group) specializing in hand-to-hand combat with full contact. The average age of all subjects was (21 ± 1.5) years.

Measures

The following indicators of the stabilogram were determined in all athletes: Length is the length of the trajectory of movement of the pressure center; AvgSpeed is an average speed of movement of the pressure center; RangeX is a range (difference between maximum and minimum coordinate) of oscillations of the pressure center in the front plane; RangeY is the range (difference between the maximum and minimum coordinates) of the oscillations of the pressure center in the sagittal plane; LengthX is the length of the trajectory of movement of the pressure center in the front plane; LengthY is the length of the trajectory of movement of the pressure center in the sagittal plane; EFQ is an indicator of the equilibrium function quality. To investigate the SDS state of the athletes, the device "MDFR stabilograph-1" (developer – LLC "ASTER-IT", Kharkiv, Ukraine) was used.

Procedure

The registration of stabilogram in the first group of athletes was carried out before and after the standard training corresponding to the level of their physical fitness. The second and third groups' athletes had the stabilogram registration after 90 minutes of training. The volume and structure of athletes training corresponded to the level of their physical fitness (Chernozub et al. 2019).

Statistical analysis

Statistical analysis of the study results was performed using the software package Statistica 6.0. Descriptive statistics methods were used to calculate the median (Me), 25% and 75% quartiles. The clustering of athletes indicators was carried out according to the k-means algorithm. Nonparametric Wilcoxon and Mann-Whitney criteria were used to assess the significance of pairwise differences.

Results

Table 1 presents the results of assessing the static and dynamic functions of athletes before and after training. It can be noted that the studied indicators have a significant scatter, which led to the hypothesis of heterogeneity of groups.

Table 1 Average results of the vestibular system indices in the athletes before and after training (Me, 25%, 75%)

Time	Indices	Group		
		1 (n=20)	2 (n=23)	3 (n=24)
Before training	L _T , mm	635.9 (527.9; 758.1)	523.9 ¹ (339.3; 599.6) Z=2.3; p=0.02	525.6 ² (365.1; 599.6) Z=2.2; p=0.03
	V _{AVR} , mm/s	10.6 (8.8; 13.1)	8.7 ¹ (5.7; 10.0) Z=2.1; p=0.04	8.8 ² (6.1; 10.0) Z=2.2; p=0.03
	ΔL _X , mm	30.3 (21.1; 41.5)	22.8 ¹ (14.3; 29.3) Z=2.1; p=0.04	21.7 ² (14.8; 24.2) Z=2.4; p=0.01
	ΔL _Y , mm	35.3 (27.9; 46.7)	23.2 ¹ (18.4; 34.6) Z=2.8; p=0.004	22.8 ² (18.7; 26.8) Z=3.3; p=0.0009
	L _X , mm	400.7 (307.5; 532.2)	295.9 ¹ (218.3; 394.8) Z=2.1; p=0.04	318.5 (225.5; 408.2)
	L _Y , mm	412.9 (352.3; 475.3)	317.8 ¹ (233.3; 369.9) Z=2.9; p=0.004	325.3 ² (270.6; 366.7) Z=2.5; p=0.01
	EFQ	69.6 (59.0; 73.2)	75.5 ¹ (66.5; 88.0) Z=-2.2; p=0.03	73.2 (66.2; 88.0)
After training	L _T , mm	677.9 (596.9; 758.2)	582* (465.4; 689.4) Z=2.68; p=0.007	625.1* (57.8; 784.4) Z=3.1; p=0.002
	V _{AVR} , mm/s	11.3 (9.9; 12.6)	9.5* (7.8; 11.5) Z=2.65; p=0.008	10.4* (8.9; 13.1) Z=3.1; p=0.002
	ΔL _X , mm	26.2 (21.4; 32.8)	25.5 (18.5; 29.0)	26.6* (19.0; 41.3) Z=2.7; p=0.006
	ΔL _Y , mm	30.9 (21.2; 42.9)	22.3 (19.7; 33.5)	27.3* (20.9; 38.3) Z=2.2; p=0.03
	L _X , mm	389.6 (340.0; 507.2)	346.1 (249.7; 446.3)	395.4* (20.9; 38.3) Z=2.6; p=0.01
	L _Y , mm	450.4 (418.5; 471.3)	393.1* (296.1; 442.4) Z=2.61; p=0.009	411.6* (338.1; 494.2) Z=3.1; p=0.002
	EFQ	63.2 (55.1; 66.9)	70.9* (61.8; 78.3) Z=2.7; p=0.007	67.8* (54.6; 73.5) Z=3.3; p=0.001

Note: * - the differences in the index values in the group before and after training are statistically significant by the Wilcoxon criterion; 1 - differences in the index values between the first and second groups are statistically significant by the Mann-Whitney criterion; 2 - differences in the index values between the first and third groups are statistically significant by the Mann-Whitney criterion.

For in-depth analysis of the research results, each group results were clustered according to the k-means algorithm. In each group, two clusters were distinguished; the assigned indices differed significantly.

Table 2 shows the results of clustering indicators of young people who are not engaged in sports; table 3 presents the results of clustering athletes of the second group; table 4 shows the results of athletes of the third group.

Table 2 Average values of indicators of the first group of athletes in clusters before and after training

Indices	Terms of registration			
	Before training		After training	
	the 1 st cluster(n=11)	the 2 nd cluster (n=9)	the 1 st cluster (n=17)	the 2 nd cluster (n=3)
Length, mm	538(469; 580)	886 (758;991)	658 (583;719) ¹ U=16; p=0.0135	1209 (1087;1331) ² U=2; p=0.033
AvgSpeed,mm/s	9.0 (7.8;9.7)	14.8 (12.6;16.5)	11.0 (9.7;12.0) ¹ U=16; p=0.0135	20.2 (18.1;22.2)
RangeX, mm	22.3 (17.9;30.3)	49.8 (37.7;75.9)	24.0 (21.0;29.5)	45.7(35.3;56.0)
RangeY, mm	29.1 (24.7;33.9)	51.0 (44.5; 56.3)	29.1 (20.7;34.3)	45.7 (43.7; 47.6)
LengthX, mm	317 (242; 365)	537 (485; 657)	376 (328;477)	740 (630;850)
LengthY, mm	364 (337; 387)	539 (457;716)	440 (412; 464) ¹ U=9; p=0.0026	796 (737;855) ² U=0; p=0.0105
KFR	72.4 (69.6; 78.8)	56.2 (40.1;65.7)	65.9 (57.3; 68.3) ¹ U=16; p=0.0135	36.4 (28.0; 44.8)

Note:¹–the differences in the index values in the first cluster before and aftertraining are statistically significant by theMann-Whitney criterion; ² -the differences in the index values in the second cluster before and aftertraining are statistically significant by theMann-Whitney criterion

Table 3 The average values of indicators of the second group of athletes in clusters before and after training

Indices	Terms of registration			
	Before training		After training	
	the 1 st cluster(n=16)	the 2 nd cluster(n=7)	the 1 st cluster(n=18)	the 2 nd cluster(n=5)
Length, mm	441 (334; 528)	621 (614;847)	533 (429;593) ¹ U=76; p=0.018	877 (862;881) ² U=5; p=0.042
AvgSpeed, mm/s	7.3 (5.6;8.8)	10.4 (10.2;14.1)	8.9 (7.2;9.9) ¹ U=76; p=0.018	14.7 (14.4;15.0) ² U=5; p=0.042
RangeX, mm	21.2 (13.3;26.6)	28.5 (22.9;40.2)	19.4 (15.5;27.3)	47.6 (37.3;68.6)
RangeY, mm	21.9 (17.7;28.8)	37.0 (21.1; 45.7)	20.2 (19.7; 26.6)	40.3 (31.6;47.2)
LengthX, mm	266 (216;312)	463 (408;535)	303 (246; 362)	604 (488; 615)
LengthY, mm	292 (210; 343)	382 (337; 549)	363 (291; 412) ¹ U=80; p=0.027	566 (494; 629) ² U=5; p=0.042
KFR	81.7 (75.3; 88.7)	63.8 (55.2;65.5)	74.1 (68.9; 80.4) ¹ U=75; p=0.017	47.3 (47.8;47.8) ² U=1; p=0.0073

Note:¹–the differences in the index values in the first cluster before and aftertraining are statistically significant by theMann-Whitney criterion; ² -the differences in the index values in the second cluster before and aftertraining are statistically significant by theMann-Whitney criterion

Table 4The average values of indicators of the third group of athletes in clusters before and after training

Indices	Terms of registration			
	Before training		After training	
	the 1 st cluster(n=15) 63	the 2 nd cluster(n=9) 37	the 1 st cluster(n=18) 75	the 2 nd cluster(n=6) 25
Length, mm	453 (303; 526)	651 (587; 743)	547 (553;634) ¹ U=46; p=0.0001	888(877; 899) ² U=5; p=0.0095
AvgSpeed, mm/s	7,5 (5,0;8,8)	10,9 (9,8; 12,4)	9,2(8,7; 10,6) ¹ U=43,5; p=0.00008	14,8 (14,7;19,0) ² U=4,5; p=0.008
RangeX, mm	16,3 (9,6; 22,2)	27,4 (24; 28,3)	25,1 (18,6; 26,8) ¹ U=66; p=0.00099	48,6 (41,3;69,8) ² U=2,0; p=0.0032
RangeY, mm	20,3 (17,4; 24,6)	25,5 (22,5;38,0)	26,0(20,5; 32,3) ¹ U=70; p=0.0015	41,7 (31,6; 57,6) ² U=4; p=0.0067
LengthX, mm	282 (209; 319)	483 (408;583)	374(246;397) ¹ U=58; p=0.00042	618 (605; 677) ² U=4; p=0.0067
LengthY, mm	295 (211;357)	367 (334;490)	399 (312; 417) ¹ U=50,5; p=0.00019	548 (498; 846) ² U=4; p=0.0067
KFR	80,2 (73,2; 91,2)	63,8(55,5; 66,0)	70,3 (65,5; 74,2) ¹ U=47; p=0.00012	47,0 (29,9;47,3) ² U=1,0; p=0.0022

Note:¹–the differences in the index values in the first cluster before and aftertraining are statistically significant by theMann-Whitney criterion; ² -the differences in the index values in the second cluster before and aftertraining are statistically significant by theMann-Whitney criterion

To conduct a comparative assessment of the impact of the training load on athletes of different groups, we carried out an analysis of the relative changes in the indicators and determined the ratio of the difference between the final and initial value of the index to the initial value of the index (Table 5).

Table 5 Relative changes in the indices of static and dynamic stability in clusters, %

Indices	Groups					
	1		2		3	
	the 1 st cluster	the 2 nd cluster	the 1 st cluster	the 2 nd cluster	the 1 st cluster	the 2 nd cluster
Length, mm	22	36	21	41	21	36
AvgSpeed, mm/s	22	36	22	41	23	36
LengthX, mm	19	38	14	30	33	28
LengthY, mm	21	48	24	48	35	49
KFR	-9	-35	-9	-26	-12	-26

Discussion

The EFQ indicator reflects the innate properties of the human vestibular system, which is sufficiently stable and resistant to external influences and can be used as an integral indicator for the evaluation of the vestibular system. Normally, the indicator varies in the range of 70-80%. It was determined that the EFQ value of 65-70% is related to "donozology", the value in the range of 0-64% and 81-100% is classified as "pathology" (Sologubov et al. 2000; Sliva, 2005; Shestakov, 2007).

If a person has no diseases or injuries of the musculoskeletal system, the hit values of the index at the intervals or its significant change as a result of physical or psychological activity indicates violations of vestibular functions.

We compared the values of the indicators before and after the training load, and between the groups using nonparametric criteria (Table 1).

Having analyzed SDS indicators, we obtained the following results. Before loading, the values of Me Length and (25%; 75%) quartiles were significantly the highest among the athletes of the first group. This fact indicates their lower functional capabilities of vestibular system in comparison with athletes of the second and third groups. The Me Length was significantly lower in both (the second and the third) groups of athletes than in the first group. The values of the quartiles of Length in the second and third groups were close in value. According to the Length indicator, athletes of the second and the third groups did not differ from each other.

AvgSpeed was significantly higher in the athletes of the first group, which also confirmed their lower vestibular functions than in athletes of the second and the third groups. The majority of indicators presented in Table 1 proved that the vestibular functions of the first group athletes were significantly worse than those of the second and the third group of athletes. After a training load, the indicators of the vestibular system of the first group athletes did not significantly change.

The second group athletes showed significant changes after training in comparison with the initial state. Such indices as Length, Length Y (the length of the trajectory of the oscillations of the pressure center in the sagittal plane), and AvgSpeed (the speed of the gravity center) increased significantly.

The third group of athletes showed significant changes in almost all indicators of the vestibular system after training in comparison with the initial state. All studied parameters significantly increased, which indicated a significant impact of the training load on the state of the vestibular system of athletes engaged in hand-to-hand combat with full contact with an opponent.

The results presented in Table 1 proved that the indicator of the equilibrium function quality slightly decreased compared to the initial state in the first group after a training load, and significantly decreased in the second and third groups, respectively.

Having received a significant scatter in the SDS indices in the study groups, their clustering was carried out. In each of the studied groups, we identified two clusters with significantly different values of the indicators, which served a condition for successful clustering. Since the composition of the clusters obtained before and after training load was different, that is the obtained samples can be considered independent, we used the Mann-Whitney criterion to assess the significance of differences in the values of the indicators.

The first group (Table 2) had 55% of the athletes assigned to the first cluster, and 45% - to the second cluster. SDS indicators in the first cluster were better than in the second, since the values of almost all indicators in this cluster were within the age norms (Kalnysh et al. 2018). The EFQ indicator in the first cluster was also within the normal range, while it was quite low in the second cluster. All indicators of the athletes assigned to the second cluster were above the age norms, which indicated low vestibular functions of the athletes belonging to this cluster. After a training load, the volume of the first cluster increased to 85% of all athletes. The SDS values of the athletes in the first cluster were within normal values. Training load led to a significant increase in the speed and length of the trajectory of the pressure center due to a significant increase in the length of the trajectory of its oscillations in the sagittal plane. Similar changes in indicators were noted in the second cluster.

Thus, a training load led to the normalization of SDS indicators in most athletes of the first group, as evidenced by a decrease in the volume of the second cluster. Changes in indicators of the first cluster indicated the development of a mobilization state in athletes. At the same time, there was a deterioration of vestibular functions as a result of fatigue in the second cluster.

There were 16 (70%) athletes in the first cluster and 7 (30%) persons in the second cluster before training in the second group (Table 3). SDS indicators in both clusters had values close to normal (Kalnysh et al. 2018), although athletes of the first cluster had the best indicators. The EFQ index was higher in the first cluster, which confirmed the higher vestibular functions of most athletes in the second group. After a training load, the volume of the first cluster increased to 78%, which can also be explained by the state of mobilization. In this cluster, the length of the trajectory of the pressure center increased significantly due to an increase in its projection in the sagittal plane, and the velocity of the pressure center. The athletes of this cluster also decreased the EFQ significantly, which may indicate the development of the state of fatigue. The same indicators significantly increased in the second cluster, but they all went beyond the normal range, especially the EFQ, which decreased by 26%. In the first cluster, this indicator decreased by only 9%. The obtained results indicated that under the influence of the training load, a significantly greater change was recorded in vestibular functions of athletes with initially worse indicators.

The third group, had 15 (63%) athletes in the first cluster, and 9 (37%) in the second cluster before training (Table 4). In both clusters, SDS indicators were within normal limits, although they were significantly higher in the first cluster. As a result of a training load, the volume of the first cluster increased to 75% of all athletes, and the volume of the second cluster decreased. All indicators of the first cluster significantly increased in comparison with the initial state, but remained within the normal range, which indicated high vestibular functions of athletes in this cluster. All indicators of the second cluster significantly increased in comparison with the initial state and exceeded the values of age norms, which confirmed the lower vestibular functions of athletes in this cluster. EFQ indicator decreased by 12% in the first cluster after a training load, and by 26% in the second cluster, which also indicated the low vestibular functions of athletes assigned to this cluster.

An analysis of the relative dynamics of the studied parameters (Table 5) showed that the athletes of each group assigned to the second cluster experienced a significantly larger change in SDS indicators than the athletes of the first cluster.

Specialists in the field of sports and sports medicine are currently studying SDS of athletes specializing in various sports at rest, during training, competitions, and rehabilitation after injuries. The studies proved that the state of the vestibular system largely determined the success of athletes in martial arts (judo and taekwondo, karate). Considering the features of SDS allows athletes to optimize their movements in the process of training and competition, maintain balance in various positions of the body (Zago et al. 2015).

Features of the vestibular functions of athletes are considered from different perspectives. The influence of SDS on sports results in different sports was also studied. The obtained results showed that athletes with high vestibular functions achieved higher athletic performance (Hrysomallis. 2011; Ricotti. 2011; Fong et al. 2013; Gosselin et al. 2014; Chow et al. 2016).

Sadowska D. et al (2019) when studying the vestibular functions of the pentathletes, revealed higher SDS indicators and lower dependence of the balance on visual control, compared with people who are not engaged in sports. The minimum amplitude of pentathletes body vibrations during shooting, according to the authors, is due to the high level of concentration of attention and conscious balance control, which is improved during training (Sadowska et al. 2019).

Wojciech Bajorek W. et al (2011) studied the balance of athletes specializing in karate, and showed that large amplitude of oscillations was observed in the main stance, in the sagittal plane, which confirmed our results. The authors revealed a significant deterioration in the studied balance indicators in the forward tilt position. The SDS indicators of stabilography with closed eyes in karate athletes did not deteriorate, which confirmed their good condition of the vertical control and balance control system for martial artists.

On the other hand, Gribble Grzegorz J. et al (2013) did not reveal the long-term positive effect of karate classes on the state of the equilibrium function of elite athletes. The authors noted an increase in the amplitude of oscillations of the body of elite athletes in comparison with people who were not engaged in sports.

Gauchard G C et al. (2017) researched the impact of visual and tactile contribution to the SDS of athletes specializing in karate (kata and kumite). Studies were conducted with open and closed eyes, on a solid and non-solid support. The results showed that athletes engaged in karate had better SDS indicators than non-athletes. Kata-karate practitioners had better SDS indicators than kumite-karate practitioners. The results showed the presence of SDS indicators depending on the technique of conducting a duel in martial arts. Similar results were obtained by other authors studying SDS indicators of martial arts athletes (Perrot et al. 1998; Leong et al. 2011; Bajorek et al. 2011; Itamar et al. 2013; Juras et al. 2013; Pop et al. 2013).

In our studies, we did not reveal significant differences in SDS indicators between athletes specializing in hand-to-hand combat with semi and full contact with an opponent (Table 1).

Most authors point to differences in the static and dynamic functions of athletes and individuals who are not engaged in sports professionally, which confirms the results obtained in our study.

Authors of most studies which we analyzed conducted research of the SDS indicators in small groups of athletes without division into subgroups, depending on the initial level of vestibular functions. Our studies revealed a sufficiently large variation in the values of SDS indicators among elite athletes and people who were not engaged in sports professionally. This suggests that the studied groups are heterogeneous in vestibular functions. To isolate homogeneous groups, we clustered the data using the k-means algorithm. After clustering athletes, we identified two clusters in each of the studied groups, which significantly differed in terms of SDS. We put athletes with high vestibular functions in the first cluster of each group, and athletes with low vestibular function into the second cluster. The first group of subjects was divided into almost equal in volume clusters (55% and 45%, respectively), which indicated the presence of low vestibular functions in almost half of the subjects who were not engaged in sports. In the second and third groups, the majority (70% and 63%) of elite athletes had rather high vestibular functions.

As a result of the training load, the number of subjects with higher vestibular functions increased slightly, which can be interpreted as a state of mobilization. In the first cluster of each group, the training load caused an increase in indicators by 20-25%, except for the EFQ indicator, which decreased by 9-12%. In athletes with low vestibular functions (the second cluster of each group), the training load led to a significantly larger (36-48%) increase in SDS indicators and a decrease in EFQ by 26-35%. Thus, a significantly more pronounced reaction to the training load was found in athletes with initially lower vestibular functions. The previous research (Kochina et al. 2019) showed that decreased vestibular function was a marker of deterioration in the functional state of athletes. Thus, the presence of low SDS values before the training load allows us to predict their deterioration after training. During the competition, athletes take part in several fights a day. Therefore initially low vestibular functions influence the results of competitions. They can also significantly affect the performance and the outcome of competitions. Thus, this phenomenon must be taken into account when conducting sports selection, formation of the structure and content of training.

Conclusions

The conducted studies showed that not only people engaged in sports professionally, but also elite athletes can have low vestibular functions. These functions may significantly decrease as a result of the training load, which indicates deterioration in the functional state and may cause poor performance in competitions. There was no significant dependence of the vestibular functions of athletes on the type (semi or full contact) of hand-to-hand combat. In addition, the results can be used in sports selection and predicting the success of athletes by SDS indicators.

References

- Adamovich R. G., Kurasa G. A., Minenko A. V., Brylev A. O. (2018). Features of the Vestibular System State in Athletes Practicing Full Contact Hand-to-Hand Combat. *Ukrainian Journal of Medicine, Biology and Sport*. V. 3, № 6. C. 328-333. DOI: 10.26693/jmbs03.06.328
- Andreev D.A., Karmazin V.V., Parastaev S.A. (2017) Comprehensive assessment of postural control as a conceptual basis for optimizing rehabilitation and recovery programs in sports. *Bulletin of RSMU*. 6. 5-11.
- Ashkinazi S.M., Klimov K.V. (2006) The basic technique of hand-to-hand combat as a synthesis of the technique of martial arts: a training method. allowance. SPb: P.F. LesgaftSPb State University of Physical Culture. 80 p.
- Bajorek, W., Czarny, P., Król, M., Rzepko, G., Sobo, A., & Litwiniuk, A. (2011). Assessment of postural stability in karate contestants. *Journal of Combat Sports and Martial Arts*, 1/2, 2.
- Balter SGT, Stokroos RJ, Akkermans E, Kingma H. (2004) Habituation to galvanic vestibular stimulation for analysis of postural control abilities in gymnasts. *Neurosci Lett*. Aug 5; 366 (1): 71–5.
- Camliguney, A. F., Ramazanoglu, N., Erkut Atilgan, O., Yilmaz, S., & Uzun, S. (2012). The effects of intensive ski training on postural balance of athletes. *Int. J. Humanities Soc. Sci*, 2(2), 71-79.
- Campos, B.T., Penna, E.M., Rodrigues, J.H., Diniz, M.A., Mendes, T.T., Filho, A.F., Franchini, E., Nakamura, F.Y., & Prado, L.S. (2018). Influence of autonomic control on the specific intermittent performance of judo athletes. *Journal of Human Kinetics* <http://dx.doi.org/10.1515/hukin-2017-0186>
- Chernozub A. A., Adamovich R. G., Shtefyuk I. K. (2019) Scientific Substantiation of the Structure and Content of the Training Load of Athletes specializing in Hand-to-Hand Combat. *Ukrainian Journal of Medicine, Biology and Sport*. Vol. 4, №5 (21). P.395-402. DOI: 10.26693/jmbs04.05.395
- Chow GCC, Fong SSM, Chung JWY, Chung LMY, Ma AWW, Macfarlane DJ. (2016) Determinants of sport-specific postural control strategy and balance performance of amateur rugby players. *J Sci Med Sport*. Nov; 19 (11): 946–50.
- de Mello, M. C., de Sá Ferreira, A., & Ramiro Felicio, L. (2017). Postural control during different unipodal positions in professional ballet dancers. *Journal of Dance Medicine & Science*, 21(4), 151-155.
- Dykyi O. (2016) Field Multiathlon as Part of Special Physical Training of Preinductions. *Physical Education, Sports and Health Culture in Modern Society*. 2. P. 32-37.

- Farnaz M., Memar Raghad M., Heydar S. (2016) Comparison of static postural stability between individuals with ankle sprain injuries and ACL reconstruction individuals. *Turkish Journal of Sport and Exercise*. 3.126-130.
- Fidler A., Haddad J. M., Gagnon J., Van Emmerik R.E.A., Hamill J. (2005) Postural control strategies in dancer and non-dancer. *ISBS*. Beijing, China. 642-645.
- Filingeri, D., Bianco, A., Zangla, D., Paoli, A., & Antonio, P. (2012). Is karate effective in improving postural kontrol? *Archives of Budo/Science of Martial Arts*. 8(4):191-194.
- Fong SSM, Tsang WWN, Ng GYF. (2013) Lower limb joint sense, muscle strength and postural stability in adolescent Taekwondo practitioners. *Int Sport Med J*. 14 (2): 44-52.
- Gagey P. M. (2008). Posturology. Regulation and Imbalance of the Human Body / P.-M. Gazhe, B. Weber; trans. from the French edition. V. I. Usachev. SPb.: Publishing house SPbMAPO, 2008. 316 p.
- Skvortsov D. (2010) Stabilometric Study. Quick Start Guide. Moscow: Mera-TSP. 2010. 171 p.
- Gauchard GC, Lion A, Bento L, Perrin PP, & Ceyte H (2017) Postural control in high-level kata and kumite karatekas. *Mov Sport Sci/Sci Mot*, 100, 21-26.
- Gosselin G, Fagan MJ. (2014) The effects of cervical muscle fatigue on balance — a study with elite amateur rugby league players. *JSports Sci Med*. May 1; 13 (2): 329-37.
- Gribble Grzegorz, J., Marian, R., Pawel, K., Wojciech, C., Wojciech, B., Kajetan, S., & Grzegorz, S. (2013). The effect of expertise in karate on postural control in quiet standing. *Archives of Budo*. 9(3): 205-209.
- Güler M., Gülmez I., Ramazanoğlu N., Yılmaz S. (2017) The Evaluation of Balance Performance for Elite Male Karate Athletes After Fatigue. *Int J Sport Exer & Train Sci*, 3 (4), 161-168. DOI:10.18826/usecabd.336577
- Hrysomallis C. (2011). Balance ability and athletic performance. *Sports Med*. Mar 1; 41 (3): 221-32.
- Itamar, N., Schwartz, D., & Melzer, I. (2013). Postural control: differences between youth judokas and swimmers. *Journal of Sports Medicine and Physical Fitness*, 53/5, 483-489.
- Juras, G., Rzepko, M., Krol, P., Czarny, W., Bajorek, W., Slomka, K., & Sobota, G. (2013). The effect of expertise in karate on postural control in quiet standing. *Archives of Budo*, 9/3, 205-209.
- Kalynysh V. V., Shvets A. V., Gorolyuk D. O. (2018). Clinical and functional features of health recovery in person with consequences of traumatic brain after staying in combat zone by indices of a stabilographic study. *Ukrainian Journal of Occupational Health*. 3(56). C. 22-33.
- Kochina M. L., Chernozub A. A., Kochin O. V., Shtefyuk I. K., Firsov O. G. (2019) The Model for Predicting Changes in the Athlete's Functional State under the Influence of Training Load. *Ukrainian Journal of Medicine, Biology and Sport*. Vol. 4, №1 (17). P.283-291. DOI: 10.26693/jmbs04.01.283
- Kompaniets O. (2001). Comparative Assessment of Existing Basic Research Methods of Vestibular Function and the Method of Computerized Posturography in Practice of Professional Selection of Candidates for Flights *Journal of Ear, Nose and Throat Diseases*. 6. P. 54-57.
- Leong, H.-T., Fu, S.N., Ng, G.Y., & Tsang, W.W. (2011). Low level Taekwondo practitioners have better somatosensory organisation in standing balance than sedentary people. *European Journal of Applied Physiology*, 111/8, 1787-1793.
- Mikotajec, K., Maszczyk, A., Chalimoniuk, M., Langfort, J., Gołaś, A., Zajc, A (2017) The influence of strength exercises of the lower limbs on postural stability: A possible role of the autonomic nervous system. *Isokinetics and Exercise Science* <http://dx.doi.org/10.3233/IES-160648>
- Paillard T, Noé F (2015) Techniques and Methods for Testing the Postural Function in Healthy and Pathological Subjects *BioMed Research International* <http://dx.doi.org/10.1155/2015/891390>
- Pardaev D.Y. (2009). Analysis competitive activity of hand-to-hand fighting sportsmen. *Uchenyey zapiski universiteti imeni P.F. Lesgafta*. 4 (50). P. 75-78.
- Perrot, C., Moes, R., Deviterne, D., & Perrin, P. (1998). Postural adapting specific combative sport movements. *Science & Sports*, 2/13, 64-74.
- Pokrovskiy V. (2007) Human Physiology / Ed. V. M. Pokrovskiy, G. F. Korotko. Moscow: Medicine, 2007. 656 p.
- Pop, T., Czamy, W., Glista, J., & Skrzypiec, M. (2013). Influence on the stability and symmetry of the load on lower limbs. *Archives of Budo*, 9/1, 39-49.
- Rannama, I., Pedak, K., Bazanov, B., & Port, K. (2017). Cycling specific postural stability during incremental exercise: The relationship with cyclists functional movement screen score. *Journal of Human Sport and Exercise*, 12(1), 83-95. doi:10.14198/jhse.2017.121.07
- Ricotti L. Static and dynamic balance in young athletes. *J Hum Sport Exerc*. 2011; 6 (4): 616-28.
- Sadowska D., Sacewicz T., Lichota M., Krzepota J. & Ladyga M. (2019) Static Postural Balance in Modern Pentathletes: A Pilot Study. *Int. J. Environ. Res. Public Health*. 16, 1760-70. <http://dx.doi.org/10.3390/ijerph16101760>
- Santos, L., Fernández-Río, J., Iglesias-Soler, E. et al (2018). Postural control and physiological responses to a simulated match in U-20 judo competitors. *Sports Biomechanics*, 1-14. <http://dx.doi.org/10.1080/14763141.2018.1461237>

- Shestakov M. (2007) Using Stabilometry in Sports / M. P. Shestakov. Moscow: TVT Divisio., 112 p.
- Shtefiuk I. K., Radchenko Yu. A., Ermakova A. O., Dovgan O. V., Abramov K. V., Briliov A. O., Tkachenko M. P. (2018). Results of the Functional State Assessment in Athletes engaged in Hand-to-Hand Combat with Semi Contact according to the Parameters of Heart Rate Variability and Static and Dynamic Stability. *Ukrainian Journal of Medicine, Biology and Sport*. Vol. 3, №7 (16). P.283-288.
DOI:10.26693/jmbs03.07.283
- Skvortsov D. (2007). Motor Pathology Diagnosis by Instrumental Methods: Gait Analysis, Stabilometry. M.: MBN, 640 p.
- Skvortsov D. (2004). Theoretical and practical Aspects of Modern Posturology / *Proceedings of the First International Symposium. Clinical posturology, posture and bite*. St. Petersburg, 2004. P. 30-32.
- Sliva S. (2005) Domestic Computer Stabilography: Technical level, Functionality and Applications *Journal of Medical Technology*. 1. P.32-36.
- Sliva S.S. (2005) Domestic computer stabilography: engineering standards, functional capabilities, and fields of application. *Biomed. Eng.* V. 39, №1. P. 31-34.
- Sologubov E.G., Yavorskii A.B., Kobrin V.I., Nemkova S.A., Sinel'nikova A.N. (2000) Use of Computer Stabilography and computer-assisted biomechanical examination of gait for diagnosis of posture and movement disorders in patients with various forms of infantile cerebral paralysis. *Biomed. Eng.* V. 34, № 3.P. 138-143
- Van Emmerik, R.E., van Wegen, E.E. (2002). On the functional aspects of variability in postural control. *Exercise and Sports Science Reviews*, 30, 177-83
- Williams III B., Murray N.G., Powell D.W. (2016) Athletes who train on unstable compared to stable surfaces exhibit unique postural control strategies in response to balance perturbations. *J. of Sport and Health Science*. 5. 70-76. <http://dx.doi.org/10.1016/j.jshs.2016.01.010>
- Winter D.A. (1995) Human balance and posture control during standing and walking. *Gait & Posture*. Vol. 3, 4. P. 193-214
- Wojciech Bajorek W., Wojciech Czarny W, Paweł Król P., Rzepko M., Sobota G., Litwiniuk A. (2011) Assessment of postural stability in traditional karate contestants. *Journal of Combat Sports and Martial Arts*. 1(2); Vol. 2, 23-29.
- Zago, M., Mapelli, A., Shirai, Y. F., Ciprandi, D., Lovecchio, N., Galvani, C., & Sforza, C. (2015). Dynamic balance in elite karateka. *Journal of electromyography and kinesiology*, 25(6), 894-900.
- Zech A.; Argubi-Wollesen A. Rahlf A.L. (2015) Minimalist, standard and no footwear on static and dynamic postural stability following jump landing. *Eur. J. Sport Sci.* 15, 279–285.