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Original Article

Optimization of the motor-sensory system of young volleyball players based on the functional state assessment of regulatory systems

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Abstract:
Purpose of the study is to improve the motor-sensory system of young athletes based on the assessment of the functional state of regulatory systems. **Materials and methods.** The study was carried out on the basis of epy Specialized Children's and Youth Sports School of the Olympic Reserve (SCYSSOR) №2 "Krasnyye kryl'ya" (Togliatti, Russia). The study involved 50 students who were divided into two groups of 25 people each, namely the main group (MG) and the comparison group (CG). To assess the functional state of the children's organism and determine parameters of the vegetative balance, neurohumoral regulation, the heart rate variability (HRV) analysis was used with the hardware-software complex "Varicard 2.51." The study of psycho-physiological indicators was carried out with the help of the computer program "Researcher of Temporal and Spatial Properties of Human – Version 2.1." The following tests were used in it: determining the reaction time to a moving object (RMO) and determining the reaction time to a choice. These techniques are used as a physiological test to determine the level of the relationship between the processes of excitation and inhibition in the cerebral cortex, both in a state of relative rest and under the influence of physical exertion. The response time to a choice is one of the variants of a complex sensorimotor reaction, since it is necessary to differentiate the signal (one signal needs to be reacted, and the other one does not have to respond). To assess the technical and physical preparedness of the practitioners, a number of control tests (standards) were used. **Results.** As a result of optimization of the functional state of the regulatory systems in the schoolchildren of 8-9 years, the parameters of motor abilities and technical preparedness of the subjects are improving, as well as the psychophysiological indices of schoolchildren. **Conclusion.** The received data clearly demonstrates that at optimization of a functional condition of an organism of children there is more effective training to technical methods of game of volleyball and development of impellent abilities of engaged pupils of 8-9 years.
Keywords: motor-sensory system, volleyball, functional state of regulatory systems

Introduction

In Russia, modern medical and biological technologies that ensure the correct organization of the physical education of young athletes are not being used enough [5, 20]. Therefore, there are separate cases of development of overtraining and overstrain of individual body systems during the training sessions (Bayevsky, Ivanov & Chireikin, 2001; Pseunok, 2005**;** Shlyk, Sapozhnikova & Shumikhin, 2007). This happens even in spite of the careful control exercised both by the trainers and sports medicine specialists (Bayevsky, Ivanov & Chireikin, 2001; Kuznetsova & Sonkin, 2009; Shlyk, 2009).

The concept of a functional state (FS) is used to characterize dynamic properties that reveal levels of activation of the organism's individual regulatory systems (Alexandrov, 2014; Anokhin, 1975). First of all, this relates to the central nervous system (CNS), the autonomic nervous system (ANS), the cardiovascular system (CCS), and the respiratory system, i.e. those systems that provide optimal performance and life of the human body (Alexandrov, 2014; Anokhin, 1975; Krivolapchuk, 2009).

It is known that in order to achieve high sports results, timely and rapid mobilization of all the body's functional systems is necessary, and their quick reconfiguration is also necessary to achieve a new and optimal level of functioning (Kuznetsova & Sonkin, 2009; Sitdikov, Iskhakova & Kuznetsova, 2009). In any training process, careful monitoring of the state of the body's regulation systems is required (Krivolapchuk, 2009; Semenov & Baevsky, 1996; Sitdikov & Samigulin, 2000). That is why it is important to select the optimal motor activity and cycles of training sessions, taking into account the reaction of the young athletes' CCS. It is important to pay attention to how the students adapt to the school curriculum, how relationships develop with their peers, and whether the domination of the individual in the team occurs. Also, it is necessary to note whether the load corresponds to the adaptive capabilities of the schoolchildren's organism and whether its acceleration occurs, because all this can affect the functional state of the young athletes involved (Dogadkina, 2011; Pseunok, 2005; Shlyk, 2009; Shlyk, Sapozhnikova & Shumikhin, 2007). It is especially important to pay attention to the

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means of recovery after training sessions and compliance with all hygienic regulations (Krivolapchuk et al., 2014; Kulagina, 2009; Sitdikov & Samigulin, 2000).

Purpose of the study is to improve the motor-sensory system of young athletes on the basis of assessing the functional state of regulatory systems.

Objectives:

1. To determine the functional state of the young athletes' regulatory systems at the initial stage of the investigation in the main group (MG) and comparison group (CG);
2. Based on the correction of the state of regulatory systems, to determine the effectiveness of training in technical techniques for playing volleyball.
3. To study the level of development of motor abilities and psycho-physiological adaptation of young volleyball players of 8-9 years with the optimization of the functional state.

Materials and methods

The study was conducted on the basis of the SCYSSOR №2 "Krasnyye kryl'ya" in the city of Togliatti, Russia during 2017-2018 in three stages. At the ascertaining stage of the study (1), indicators of the organism's functional state of the children aged 8-9 years were studied using the HRV analysis method (50 boys), namely in the MG (25 schoolchildren) and CG (25 schoolchildren). Young athletes were engaged in volleyball at the stage of initial preparation of the second year of training. The initial indices of development of motor abilities and technical preparedness of boys were determined. At the stage of the formative experiment (2), the technique of teaching the technical methods for playing volleyball for boys aged 8-9 on the basis of indicators measuring the functional state of regulatory systems was tested, additionally focusing on the psychophysiological indices of students. At the control stage of the experiment (3), a comparative evaluation and analysis of the results obtained after optimizing the functional state of the regulation systems of volleyball training techniques, as well as the development of motor abilities and technical readiness, was conducted.

The method of analyzing the heart rate variability (HRV).

To determine the functional state of children's CCS, the software and hardware complex (SHC) "Varikard 2.51" was used, which ensures the implementation of all the main methods of the HRV analysis:

- making medical and physiological conclusions about the state of vegetative regulation of blood circulation with an evaluation of the degree of tension existing in the body's regulatory systems;
- saving the analysis results and baseline HRV data (ECG, cardiointerval series) in the data bank, providing the opportunity to access it for conducting a detailed analysis or comparative evaluation;
- displaying the HRV analysis results on the monitor screen during the input of ECG signals of the measured parameters with their mean values (heart rate, number of cardio intervals, time scale) (Bayevsky, Ivanov & Chireikin, 2001; Semenov, 2014; Semenov & Baevsky, 1996; Shlyk, Sapozhnikova & Shumikhin, 2007).

The computer program "Researcher of Temporal and Spatial Properties of Human – Version 2.1."

We used a number of tests.

Test 1: Determining the reaction time to a moving object (RMO).

It is known that RMO is considered as a reaction to the anticipation of an event, the strength of which depends on the speed of the object being watched, and as a reflex to time. RMO is used as a physiological test to determine the level of interaction between the processes of excitation and inhibition in the cerebral cortex, both in a state of relative rest and under the influence of physical exertion. With the help pf RMO indicators, one can, to a certain extent, judge the stability of tthe nervous system's functioning.

The RMO investigation: the subject follows a red circle moving in a spiral toward the center of the monitor screen (indicated by a black cross); when the movement ends is the stimulus for determining the time of the motor reaction. The computer automatically calculates the response time, and, in the case of advanced reactions, the lead time (Koryagina & Nopin, 2004; Nopin & Koryagina, 2003).

Test 2: Determining the response time to a choice.

The response time to a choice is one of the variants of a complex sensorimotor reaction, since it is necessary to differentiate the signal (one signal needs to be reacted and the other one does not have to respond). This leads to an increase in response time due to the "central delay," i.e. the time that goes to differentiate the signal, to remember how to respond to a particular signal. The "central delay" from the time of a complex reaction can be identified by subtracting the time of a simple reaction being measured in the same person. The time of "central delay" is greater in individuals with an average strength of the nervous system, and it is less in persons with a strong nervous system. Investigation of the response time to a choice consists in proposing to the subject to choose from two stimuli of a large and a small red circle appearing randomly in the center of the monitor screen. It is necessary to respond (by pressing the spacebar) only to the appearance of a small circle. The computer automatically fixes time from the appearance of a small circle to pressing a key (Koryagina & Nopin, 2004; Nopin & Koryagina, 2003).

Mathematical and statistical analysis. The results were processed using the statistical software Stat.exe for Windows. The reliability of the results is ensured by the interrelation between the theory and practice of the

research, supported by the use of scientific methods of comparing the averages for independent and paired samples by the T-test.

Research conditions.

The evaluation of HRV indicators, technical preparedness, and the level of development of motor abilities was performed in the dynamics of the training process at the beginning and end of the workout.

1. The HRV assessment was conducted before and after the volleyball training session. The recording of the electrocardiogram was performed in the supine position in a state of relative rest. The recording time was 5 minutes before and after the workout.

2. Psychophysiological indicators were evaluated in a specialized room in which there were a calm atmosphere and no outside noise. Subject, sitting in front of the computer, fulfilled the necessary testing conditions.

Technical preparedness and motor abilities were evaluated by means of control tests corresponding to the age of the children.

1. Technical readiness:

- "Passing the ball from above with two hands from zone 3 to zone 4."
- "Receiving the ball from below with two hands from zone 6 to zone 5."
- "Innings" [4].

2. Assessment of the level of development of motor abilities was carried out with the help of the following control tests"

- "Running 30 m";
- "Shuttle running 5 × 6 m";
- "Jumping long";
- "Jumping up from a place with two feet";
- "Throwing a stuffed ball from a standing position" (Shulyatiev & Pobyvantsev, 2012).

Methods of teaching the technique of playing volleyball.

Building a program of teaching technical techniques for playing volleyball, we paid special attention to the technique of moving around the volleyball field. In the training process of boys involved in volleyball, we included a large number of movements, jumps, turns, stops, and simulation exercises. Some movements were performed under a certain rhythm of claps.

Using an assessment of the state of regulatory systems, the training process in the MG was adjusted, which helped to optimize the functional status of those involved and prevent fatigue. Classes were held four times a week for 90 minutes.

In the main part of the training session, exercise complexes were used to correct the functional state, reduce the voltage of the regulatory systems, including:

- Exercises of general physical preparation of low intensity;
- Between the tasks of technical training were included aerobic exercises of low intensity for 1 minute;
- An exercise to relax the muscles from callanetics and stretching.

In the final part of the lesson, exercises from the complex of callanetics were used, which were performed in different starting positions, sitting, at the support and lying down. These exercises were combined into mini complexes and performed in each lesson.

The proposed methodology included a large variety of exercises that introduced novelty and high emotional component in the training sessions of boys engaged in volleyball. The game and competitive method was also applied. In the training process of the comparison group, standard techniques were used to formulate the technique of playing volleyball. Classes were held three times a week for 90 minutes.

Results

1. Results of the ascertaining experiment

At the younger school age, which corresponds to the period of the second childhood (7-12 years for boys), the development of the organism and the formation of the central nervous system continue. Therefore, it is very important in the training process to manage the functional state of the young athletes involved and to prevent disruptions in adaptation (Krivolapchuk, 2009; Sitdikov & Sheikhelislamova, 2008; Shlyk, Sapozhnikova & Shumikhin, 2007).

This will ensure the optimal functional state, improve the capabilities of the motor-sensory system necessary for the perception of space and movement changes, which is especially important in the implementation of precise movements and movements requiring rapid change of direction and speed (Koposova, Zvyagina & Morozova, 1997; Krivolapchuk et al., 2014; Krivolapchuk, 2009; Rusalov, 1991).

At the initial stage of the study both in the MG and CG, the state of tension of the regulatory systems of the children's organism was determined, and premorbid functional states were also revealed. The MG has the functional class No 5 (Figure 1), and the CG has the functional class No 6 (Figure 2).

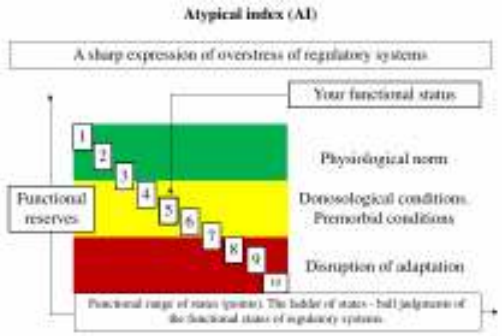
At the beginning of the study in the MG and CG, we analyzed the following cardiorespiratory parameters: the heart rate (HR) and the degree of stress of regulatory systems (Si). An increase in HS and Si in

both groups was found. At the end of the study, we observed optimal results in the MG, which confirms the correctness of the approach to the training process (Table 1), and the increased values in CG, where excess rigidity of the functional systems supporting the vital functions of children was recorded. This is also evidenced by the high rates of Si and HR, de-regulating performance of technical techniques when playing volleyball (Table 2).

Main indicators of heart rate

Index	Value	Norm
Heart rate, str./min	110	55-80
Mean square deviation, msec,	26.1	30-100
Stress index, st. un.	235	50-150

(a)

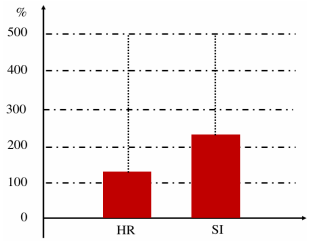


(b)

Assessment of the state of regulatory systems

Level of functioning	
Received tachycardia	2
Stability of regulation	
Increased stability of the rhythm	1
Vegetative homeostasis	
Moderate predominance of the sympathetic nervous system	1
Activity of the sympathetic vascular center	
Moderately increased activity of the vascular center	1
Degree of centralization	
Normal activity of central regulation levels	0

(c)



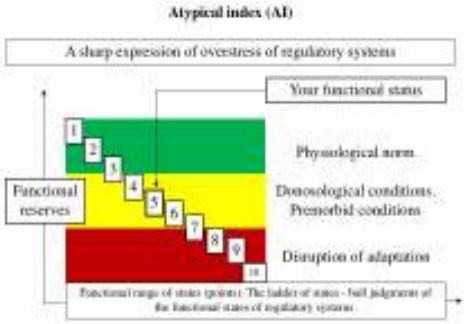
(d)

Fig. 1. Functional state and assessment of regulatory systems in the MG at the beginning of the study.

Main indicators of heart rate

Index	Value	Norm
Heart rate, str./min	115	55-80
Mean square deviation, msec,	167.5	30-100
Stress index, st. un.	184	50-150

(a)

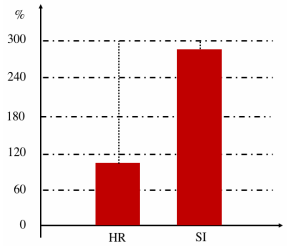


(b)

Assessment of the state of regulatory systems

Level of functioning	
Moderate bradycardia	-1
Stability of regulation	
Severe arrhythmia	-2
Vegetative homeostasis	
Expressed predom. of the parasympathetic nervous system	-2
Activity of the sympathetic vascular center	
Normal activity of the vascular center	0
Degree of centralization	
Sharp decrease in activity of central levels of regulation	-2

(c)



(d)

Fig. 2. Functional status and assessment of regulatory systems in the CG at the beginning of the study.

Table 1. HR and Si in the MG and CG during the study.

Cardiorespiratory parameters	CG at the beginning of the study	CG at the end of the study	MG at the beginning of the study	MG at the end of the study
	M±m	M±m	M±m	M±m
HR	115±3,65	90±3,64	110±3,62	80±3,64**
Si	284±7,87	347±8,97	235±0,71	124±2,71**

Note to Table 1:
M – average value, m – error of the mean value, p – confidence level, ** – p □0,01.

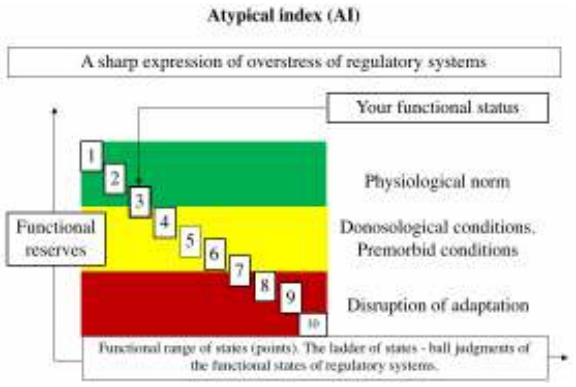
At the end of the study, as a result of the correction of the cycle of training sessions, mainly the functional class No 3 was observed in the MG, which characterizes the physiological norm, and the optimal

operation of regulatory systems ensuring the optimal motor activity of young athletes (Fig. 3, Table 3). In the CG, the functional class No. 8 was observed, which is characterized by a breakdown in the physiological adaptation of the children's organism (Fig. 4).

Main indicators of heart rate

Index	Value	Norm
Heart rate, str./min	80	55-80
Mean square deviation, msec,	61.9	30-100
Stress index, st. un.	124	50-150

(a)

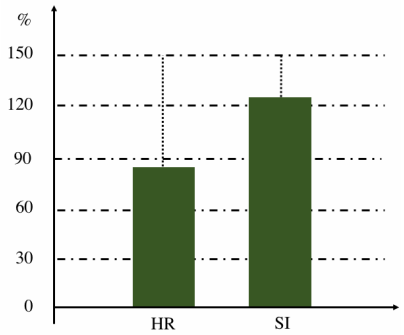


(b)

Assessment of the state of regulatory systems

Level of functioning	
Normocardia	0
Stability of regulation	
Normal rhythm stability	0
Vegetative homeostasis	
Normal vegetative balance	0
Activity of the sympathetic vascular center	
Moderately reduced activity of the vascular center	-1
Degree of centralization	
Normal activity of central levels of regulation	0

(c)



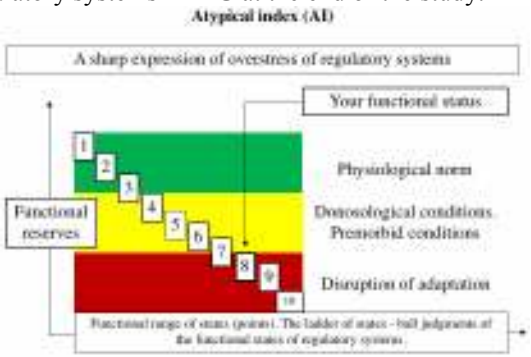
(d)

Fig. 3. Functional state and evaluation of regulatory systems in MG at the end of the study.

Main indicators of heart rate

Index	Value	Norm
Heart rate, str./min	90	55-80
Mean square deviation, msec,	18.7	30-100
Stress index, st. un.	347	50-150

(a)

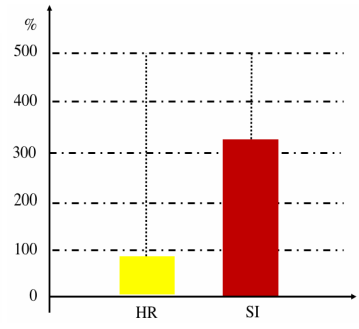


(b)

Assessment of the state of regulatory systems

Level of functioning	
Received tachycardia	2
Stability of regulation	
Increased stability of the rhythm	2
Vegetative homeostasis	
Increased predominance of the sympathetic nervous system	2
Activity of the sympathetic vascular center	
Normal activity of the vascular center	0
Degree of centralization	
Increased activity of central regulation levels	2

(c)



(d)

Fig. 4. Functional state and evaluation of regulatory systems in the CG at the end of the study.

Optimization of the functional state of the body of boys (8-9 years) in the MG effectively influences the process of mastering the technical methods of playing volleyball unlike in the CG. At the end of the test, repeated testing showed that during the experiment, there were significant changes in most of the technical readiness indicators in the MG ($p < 0.05$), unlike it was in the CG (Table 2).

Table 2. Dynamics of indicators of technical readiness of young volleyball players of the MG and CG before and after the research.

Tests	Groups			
	CG (M±m)		MG (M±m)	
	Before	After	Before	After
Passing the ball from above	2,8±0,19	3,4±0,24	2,9±0,22	4,2±0,29*
Receiving the ball from below	2,3±0,14	3,0±0,18*	2,5±0,17	4,3±0,25**
Innings	2,4±0,15	2,6±0,13	2,3±0,16	3,4±0,27*

Note: indicators are indicated in points; M is an indicator of the mean; m is the error of the arithmetic mean; * – p < 0,05; ** – p <0,01.

The use of special exercises in the training process in MG, including muscle relaxation exercises, aerobic exercises, helps to optimize the functional state of the children's organism and ensure the optimal development of special motor abilities (Semenov & Baevsky, 1996; Shlyk, 2009) (Table 3).

Table 3. Dynamics of indicators of motor abilities in the CG and MG at the beginning and end of the study.

Tests	Groups			
	CG (M±m)		MG (M±m)	
	Before	After	Before	After
Running 30 m, sec.	8,09±0,13	7,7±0,15*	8,06±0,13	7,3±0,12**
Jumping long, cm	118,1±2,2	121,3±1,9	117,7±1,8	127,9±1,8*
Shuttle running 5 × 6 m, sec.	14,6±0,13	14,4±0,17	14,4±0,2	13,7±0,08**
Throwing a stuffed ball from a standing position, m	4,81±0,21	5,62±0,09	5±0,18	6,02±0,07*
Jumping up from a place with two feet, cm	24,2±0,7	27,2±0,9*	22,4±0,8	29,8±0,8**

Note: indicators are indicated in points; M is an indicator of the mean; m is the error of the arithmetic mean; * – p < 0,05; ** – p < 0,01.

The study found that stabilization of the functional state of the children's organism contributes to the improvement of the motor-sensory system involved (Koposova, Zvyagina & Morozova, 1997; Sitdikov, Iskhakova & Kuznetsova, 2009; Shlyk, 2009).

At the beginning of the study, the RMO test, with which it is possible to determine the relationship between the processes of excitation and inhibition in the cerebral cortex and the stability of its functioning, showed average values in both MG and CG (Table 4).

At the end of the study, we observed a decrease in the time of delayed and advanced reactions in the MG, the values corresponded to a high estimate, and in the CG, despite the improvement, their values corresponded to an average estimate (Table 4).

Table 4. RMO in the MG and CG during the study.

Test RMO test	MG at the beginning	Evaluat.	MG at the end	Evaluat.	CG at the beginning	Evaluat.	CG at the end	Evaluat.
	M±m		M±m		M±m		M±m	
Leading reactions	2,1±0,12	Average	1,1±0,03*	High	1,8±0,09	Average	2,1±0,12	Average
Delayed reactions	3,9±0,15		1,8±0,09**		4,1±0,17		3,5±0,13	
Minimum values	5,1±0,21		2,1±0,12*		5,2±0,22		5,2±0,2	

Note: M is an indicator of the mean, m is the error of the arithmetic mean, p is the confidence level, * – p < 0,05; ** – p < 0,01.

The response time to a choice is one of the variants of a complex sensorimotor reaction, since it is necessary to differentiate the signal, i.e. one signal needs to be reacted, and the other does not. The response time to a choice was not very different at the beginning of the study both in the MG and the CG and related to the average score (Table 5). At the end of the study, in the MG, the indicators corresponded to a high estimate; in the CG, the values remained at the same level and corresponded to an average estimate (Table 5).

Table 5. Determining the MG and CG reaction time to a choice during the study.

Groups	Determining the response time of the selection, (c) (M±m)	Evaluation
MG at the beging	0,34±0,05	Average
MG at the end	0,21±0,05**	High
CG at the beging	0,43±0,02	Average
CG at the end	0,37±0,02*	Average

Note: M is an indicator of the mean, m is the error of the arithmetic mean, p is the confidence, * – p < 0,05; ** – p 0,01. Thus, by optimizing the work of the central nervous system and its vegetative centers, there is an improvement in the work of the vestibular-visual and proprioceptive functions, which are of particular importance for performing both the volleyball player's volitional movement and ensuring the adaptation of the child's organism to mastering new techniques (Koposova, Zvyagina & Morozova, 1997; Krivolapchuk, 2009; Shlyk, Sapozhnikova & Shumikhin, 2007). In modern conditions of the training process, the optimization of the

FS will prevent dysregulation and overtraining of the organism of young athletes already at the initial stages of exercising. Thus, the considered features of the functional state of regulatory systems indicate the need to use special remedial classes in the process of physical education, which would allow to stimulate the reserve capabilities of the organism of young athletes, contributing to the preservation and promotion of health.

Conclusion

Optimization of the motor-sensory system of young volleyball players based on the correction of the functional state is necessary in the conditions of the training process and contributes to better development of the technical techniques of playing volleyball. In the control of the FS, the processes of excitation and inhibition in the cerebral cortex are balanced. The performance of a complex sensorimotor reaction improves, which determines the stability of the functioning of the nervous system during the training process. The obtained results prove an increase in the technical preparedness, motor abilities, and psychophysiological adaptive capabilities of young athletes, under the influence of physical exercises aimed at managing the FS of those being involved.

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