Innovation Technology of Evaluation of Adaptation of Paralympic athletes to High Altitudes and Its Relation to the Properties of the Nervous System

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Abstract: Results of the investigation of Paralympians (skiers, biathletes, athletes with lesions of the musculoskeletal system) adaptation to high altitudes during the pre-competition and competition periods, as well as a search for specific psychophysiological qualities contributing to successful adaptation to high-altitude training and competition burdens is presented in this paper. The athletes included 2 women and 12 men; 6 athletes of top level, age 32.5+/-8, (LW5/7, LW6, LW8, LW10, LW12 in accordance with International Paralympic Committee classification), 5 athletes of middle level, age 24+/-5 (LW2, LW12) and 3 preparatory level, 17 years old (LW8). It was demonstrated that knowledge of the properties of the nervous system of an athlete enables the prediction of his adaptability to training and competitive activities at high altitudes. The GDV "Bio-Well" device used in the study yields a sufficiently accurate estimation of the parameters of the psychophysiological state of athletes. The "Prognoz" method for assessing the properties of the nervous system enables prompt monitoring of the process of adaptation to the high athletes during the pre-competition and competition periods and timely implementation of the necessary corrective measures. Monitoring of athletes' activity for a long time allowed creating the optimal training process and preparing athletes for completions in the peak of their adaptation, physical and psychological readiness. The best indication was successful performance of this team at Paralympic Winter Games Sochi-2014. Athletes on Russia Paralympic Team achieved commendable results in biathlon: Gold – 7, Silver – 5, Bronze – 3, as well as in skiing: Gold – 10, Silver – 3, Bronze - 6. These are remarkable results, which was achieved by combining efforts of coachers, psychologists and scientists.

Keywords: Paralympic sport, Electrophotonic Imaging, psychophysiological adaptation, nervous system, GDV Bio-Well.

1. Introduction

A distinctive feature of the 2014 Winter Olympic and Paralympic Games in Sochi was that many of the sporting events took place at high altitude. The venue for holding the cross country skiing and biathlon competitions was located on the Psekhako Ridge in the Krasnaya Polyana village. The field was located at an altitude of 850-1430 meters (2790-4660 feet) above sea level. The choice of altitude for the venue was not random: according to the requirements of the FIS and IBU internationals federations, 1400 -1600 meters (4600-5250 feet) above sea level is the optimal altitude for biathlon and cross-country skiing competitions. These conditions called for serious analysis of the psychophysiological adaptation of athletes, in particular the Paralympians (skiers, biathletes, athletes with lesions of the musculoskeletal system), to high altitudes. This problem has already been studied by us during the training period [1]. The next step was to study the adaptation of Paralympians to high altitudes during the pre-competition and competition periods, as well as a search for specific psychophysiological qualities contributing to successful adaptation to high-altitude training and competition burdens.

The problem of express-evaluation of the psycho-physiological condition of athletes for timely correction of the training process is actual for all kinds of sport and for Paralympic sport in particular [1-4]. The most essential this problem for the top-level athletes preparing for competitions, where fixed equipment is, as a rule, is unavailable, and express evaluation using hand-held devices is desirable [5,6]. One more important moment is time constrains: athletes' daily routine is toughly scheduled, and to find time for measurements is not easy, and even more so in the time of competitions. Athletes and coachers would never agree to frequent long-term analysis, so the process of measurements should be fast and, of course non-invasive. This dictates selection of the operational methods and setup.

The goal of this study was to test innovation Russian technology for express-evaluation of athletes' level of preparation in the training and competition periods and develop most efficient parameters for the practical applications.

2. Study Methods

The following methods and corresponding hand-held devices for athletes' express-analysis were used in the study:

Evaluation of Psychophysiological Stability (PS) parameter by the innovative Russian system: Electrophotonic Imaging (EPI) based on Gas Discharge Visualization technique with "Bio-Well" device (Bio-Well Co, USA www.bio-well.com). Calculation of Psychophysiological Stability (PS) index is based on image processing technique [7]; multiple experiments demonstrated that this parameter has high level of correlation with psycho-physiological condition of an athlete; it is calculated in percent from 0 to 100%; PS = 100% is correlated with high level of competition readiness and high energy reserve. Interpretation criteria are given in Table 1.

EPI Technique is based on a well-known Kirlian effect: when an object is placed on a glass plate and stimulated with current, a visible glow occurs, the gas discharge. With electrophotonics (EPI/GDV) cameras, the Kirlian effect is quantifiable and reproducible for scientific research purposes. Images captured of all ten fingers on each human subject provide detailed information on the person's psycho-somatic and physiological state [8,9]. The EPI camera systems and their accompanying software are being used in medicine and psychology [10-17]. Through investigating the fluorescent fingertip images, which dynamically change with emotional and health states, one can identify areas of congestion or health in the whole system. The parameters of the image generated from photographing the fingers under electrical stimulation creates a neurovascular reaction of the skin, influenced by the nervous-humoral status of all organs and systems. In addition, for most healthy people EPI readings vary less than 10% over time, indicating a high level of precision in this technique [18]. It is interesting to note that in the process of several years of using EPI technology for studding paralympic teams of Russia no significant differences between paralympic athletes and healthy population was found. At the same time, analysis of data for handicapped people in Russia with the same type of problems indicated much worse state of their psycho-physiological condition. This tells us about strong positive effect of sport for the overall condition of people. EPI complex is accepted as one of the techniques for athletes' state express-evaluation by Russian Ministry of Sport [19, 20].

Table 1. Interpretation criteria for Psychophysiological Stability index

PS	Description of Condition
100%-80%	High level of psycho-physiological condition.
80%-60%	Affordable level of psycho-physiological condition.
60%-40%	Acceptable level of psycho-physiological condition. Energy and emotional depletion is possible; risk of traumas; overtraining.

40%-0%	Energy and emotional depletion; high level of stress; risk of traumas; overtraining. Detailed medical analysis is needed.

EPI parameters were measured with Bio-Well device daily before noon. The time needed for measurement is less than 3 minutes, which allows collecting data without distracting athletes from the process of preparing for training or competition. Data processing is performed in real time, which yields immediate information about the state of the athlete.

To analyze the factors responsible for the psychophysiological adaptation of athletes to high altitudes during the pre-competition and competition periods, the study used sensorimotor measurement techniques [21] for assessing the following properties of the nervous system (PNS):

1. The strength of the nervous system. From the perspective of strength, three nervous system types can be identified: a strong nervous system, a medium-strength nervous system, and a weak nervous system.

2. From the perspective of the mobility of excitation and inhibition processes in the nervous system, the following types can be identified: the high excitation mobility, low excitation mobility, high inhibition mobility, low inhibition mobility, medium mobility for both processes.

3. We can identify two types of nervous process balance: "external" balance of nervous processes (the ratio of excitation to inhibition on the emotional-motivational level); "internal" balance of nervous processes (the ratio of excitation to inhibition on the energy level, where the need for activity emerges). Accordingly, there are three options of the ratios: the predominance of excitation, the balance of nervous processes, and the predominance of inhibition.

3. Participants

The study was conducted in 2013 at the following training sessions (TS) and sporting events: 1) TS1, 08.01-19.01, St. Moritz, Switzerland, 2) TS2, 27.01-05.02, St. Moritz 3) Russian Cross-Country Skiing and Biathlon Championship and TS3, 13.02-20.02, Sochi, 4) TS4, 08.03-12.03, St. Moritz; 14.03-21.03, Cross-Country Skiing and Biathlon World Cup Finals, Sochi. All sporting events were held at an altitude of about 2000 meters (6600 feet) above sea level. A total of 14 athletes from Russia's Skiing and Biathlon Paralympic Team volunteered to participate in this study. The athletes included 2 women and 12 men; 6 athletes of top level, age 32.5+/-8, (LW5/7, LW6, LW8, LW10, LW12 in accordance with International Paralympic Committee classification), 5 athletes of middle level, age 24+/-5 (LW2, LW12) and 3 preparatory level, 17 years old (LW8). All athletes participated in the study voluntary and with great interest; ethical considerations were taken into account.

4. Results

The hypothesis of the study: the properties of the nervous system (PNS) constitute one of the factors associated with successful psychophysiological adaptation of athletes to high altitudes, that is, there exists a such set of PNS (which can be dubbed 'positive'), whereby the athletes who possess it are more likely to achieve a higher level of adaptation to training and competition burdens in high-altitude conditions.

For convenience, the full duration of each of the sporting events mentioned above was subdivided into three-day phases (First phase – day 1,2,3; second phase – day 4,5,6; et cetera). When analyzing the results of the study the EPI parameters were calculated as the arithmetic mean of the parameters for all athletes during the given phase. The dynamics of the EPI parameters, as indicators of psychophysiological state of athletes during the pre-competition and competition periods of 2013, are shown on the graph in Figure 1.

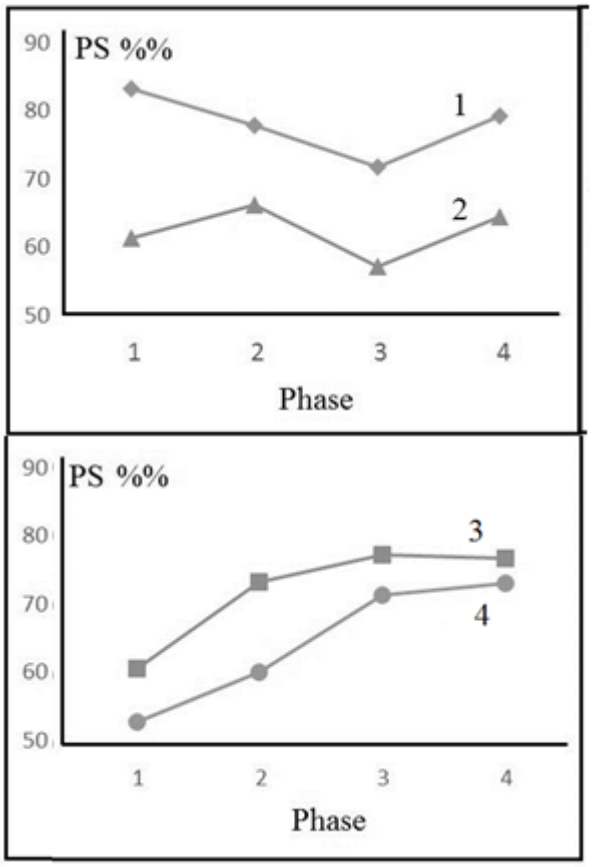

Figure 1. The change in the Psychophysiological Stability parameter during the 2013 sporting events: 1 - TS1, 08.01-19.01, St. Moritz; 2 - TS2, 27.01-05.02, St. Moritz; 3 - Russian Championship and TS3, 07.02-20.02, Sochi; 4 - TS4, St. Moritz and World Cup finals, Sochi, 08.03-21.03.

The charts in Figure 1 show that that over the TS1 and TS2 periods (curves 1 and 2) during phase 3 (days 7,8,9), there was a decrease in the team's average PS parameter. Over the last phase 4 of the event (days 10,11,12) PS values reached maximum levels, which characterizes the process of the athletes' adaptation to high altitudes. In the days of the

Russian Cross-Country Skiing and Biathlon Championship, as well as during TS3, which was held immediately thereafter, the PS parameter was increasing every day, reaching high values by the end of the analyzed period. These trends in the dynamics of parameter values may indicate the presence of certain regularities in the processes of the adaptation of athletes to the training and competition burdens under the conditions of high altitudes. Over the TS4 period before the World Cup finals, (graph 4), PS was 52% in the early days. These lower PS levels could be tied to the fact that the team arrived at the event immediately after the Cross-Country Skiing and Biathlon World Cup (22.02-06.03, Sweden). By the beginning of the World Cup finals athletes sufficiently adapted to the altitude (see 3rd and 4th phases, graph 4) and the average PS values of the team had stabilized at a fairly high level (above 70%).

When considering the issue of adaptation to training burdens at high altitudes, it may be of interest to compare data regarding the changes in the psychophysiological state of athletes during events that are similar in terms of the kind of sports offered, but distinct temporally. For example, consider the changes in PS: 1) at the beginning of the competition season in 2012 and in 2013; 2) on the eve of the Russian Championship in 2012 and in 2013. The data are presented graphically in Figure 2.

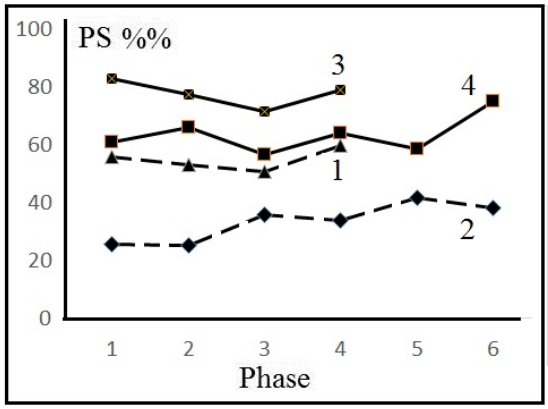

Figure 2. The Psychophysiological Stability parameter values in Russia'a cross-country skiing team (curves 1 and 3) and biathlon (curves 2 and 4) during a high-altitude training sessions: 1) at the beginning of the competition season of 2012 and of 2013. (curves 1 and 2); 2) on the eve of the Russian Championship in 2012 and in 2013 (curves 3 and 4).

When comparing curves 1 and 2, as well as 3 and 4 on the graphs in Figure 2, we can see that PS values of skiers and biathletes at high-altitude, the time difference between them being about a year, are higher in 2013. (These values became even bigger in the beginning of 2014, which was one of the reasons of Russia team success at Sochi Winter Paralympic Games).

Results of studying the process of the Paralympians' psychophysiological adaptation to high altitudes in pre-competition and competition periods, as show in the Fig. 1 and Fig. 2, may indicate that the adaptive capacity of skiers and biathletes increase with the number of training cycles in high-altitude conditions. This is phenomenon of, so to speak, "adaptive memory," when a man who has already gone through the adaptation process in the mountains adapts faster when finding himself in the mountains even many months later. Our data support the need for multiple trips to the alpine training camps during preparation for important competitions that take place at high altitudes.

In order to investigate a possible connection between the PNS and the characteristics of human adaptation to high-altitude conditions, the same group of paralympic athletes was split into subgroups according to the degree of the five typological features of their nervous system:

1) with a medium-strength or strong nervous system – 9 people, with a weak n.s. - 5 people;

2) with a medium or high mobility of excitation - 6 people., with a low mobility of excitation - 8 people;

3) with a medium or high mobility of inhibition - 7 persons., with a low mobility of inhibition - 7 people;

4) with a predominance of excitation in the external ratio (external excitation) - 11 people, with a predominance of inhibition in the external ratio (external inhibition) - 3 people;

5) with a predominance of excitation in the internal ratio (internal excitation) - 9, with a predominance of inhibition in the internal ratio (internal inhibition) - 5 people.

Given a balance in the external and internal ratios, the classification of an athlete into a particular typological group utilized an additional criterion – a balance with a shift in the direction of excitation or inhibition. In the first case, the diagnosis was external or internal excitation; in the second - external or internal inhibition.

Next, when considering the impact of PNS on adaptation processes, sporting events are presented separately - five training sessions (TS), Russian Championship, and the 2013 World Cup finals. The list also includes the event, which was held in January 20-26 (Einsiedeln, Switzerland) at a lower altitude. The criterion of adaptation of athletes, is derived by averaging the values of PS for the athletes in each group during a given sporting event. The obtained relations for each of the five PNS are presented in Figures 3-6.

The graphs in Fig. 3-6 show the 2013 sporting events in the following order (1-7 phases of the graphs): 1) TS, 08.01-19.01, St. Moritz 2) TS, 20.01-26.01, Einsiedeln 3) TS 27.01-05.02, St. Moritz 4) Russian Championship, 07.02-12.02, Sochi, 5) TS 13.02-20.02, Sochi, 5) TS 08.03-12.03, St. Moritz 7) World Cup finals, 14.03-21.03, Sochi.

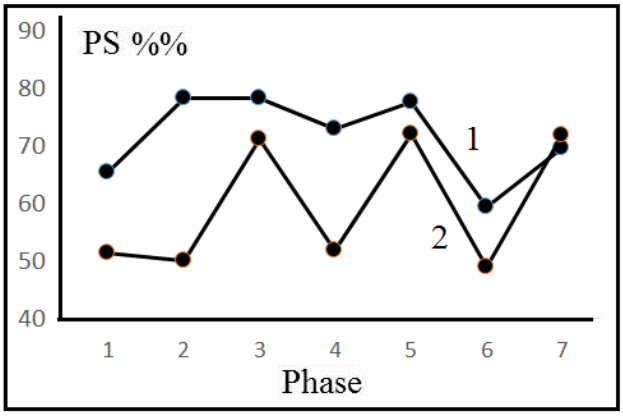

Figure 3. Changes in PS during the 2013 sporting events for the groups of Paralympic athletes with a strong (curve 1) and weak (curve 2) nervous system. Phases of the sporting events 1) TS, 08.01-19.01, St. Moritz 2) TS, 20.01-26.01, Einsiedeln 3) TS 27.01-05.02, St. Moritz 4) Russian Championship, 07.02-12.02, Sochi, 5) TS 13.02-20.02, Sochi, 5) TS 08.03-12.03, St. Moritz 7) World Cup finals, 14.03-21.03, Sochi.

From the graphs shown in Figure 3 it follows that the group of athletes with a strong nervous system was characterized by a higher level of PS than the group of athletes with a weak nervous system, in which the PS parameter significantly changed during the year.

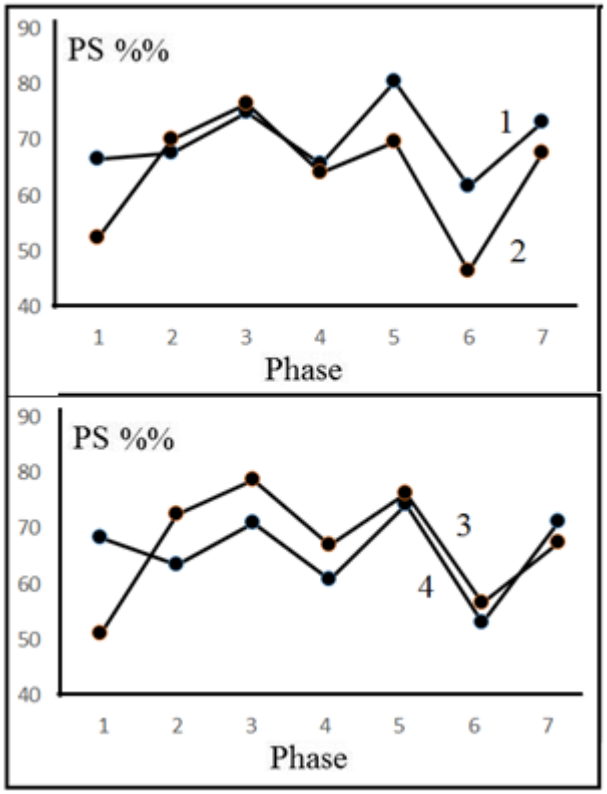

Figure 4. Changes of PS during the 2013 sporting events in the groups of Paralympic athletes with low mobility (curve 1) and high mobility (curve 2) of the excitation processes, and with low mobility (curve 3) and high mobility (curve 4) of inhibition.

The graphs in Figure 4 show that the group of athletes with low mobility of excitation was characterized by a higher level of PS after a period of adaptation than were the athletes with high mobility of excitation. At the same time, the group of athletes with high mobility and with low mobility of the inhibition processes differed little from each other in terms of the PS parameter.

From the graphs in Figure 5 it follows that the group of athletes with a predominance of both external and internal excitation was characterized by a higher level of PS than in the group of athletes with a predominance of inhibition, in which the PS parameters only stabilized toward the end of the competition season.

To summarize the patterns identified in the analysis of data in Fig. 3-5 graphs, it can be assumed that athletes with a specific typological set of PNS which can be dubbed 'positive', that is: - strong nervous system, - low mobility of excitation, - predominance of excitation in the external and internal ratios, have a higher level of adaptive capacity for training and competitive processes at high altitudes.

Conversely, athletes with a typological set of PNS which can be dubbed 'negative', that is: - weak nervous system, - high mobility of excitation processes, - predominance of inhibition processes in the external and internal ratios, are characterized by a reduced level of adaptive capacity for training and competitive processes at high altitudes.

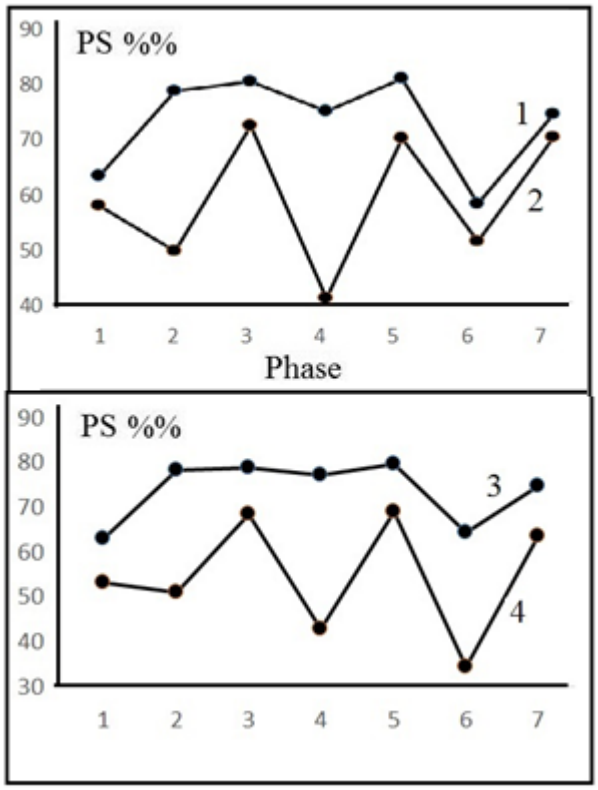

Figure 5. Changes in PS during 2013 sporting events in the groups of Paralympic athletes with a predominance of excitation (curve 1) or inhibition (curves 2) in the external ratio and excitation (curve 3) or inhibition (curves 4) in the internal ratio.

The dynamic of changes in PS in groups of athletes with positive and negative typological complexes of PNS is summarized in Fig. 6.

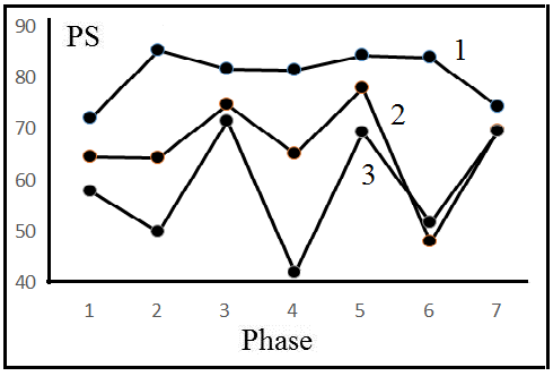

Figure 6. The dynamic of the changes in PS index in the groups of athletes with positive and with negative typological set of PNS. 1 - athletes with four PNS that are part of a positive typological set (4 people); 2 – athletes with three PNS that are part of a positive typological set (7 people); 3 – athletes with four PNS that are part of negative typological set (3 people).

From the graphs shown in Figure 6 it follows that the group of athletes with PNS consistent with the composition of the positive typological set is characterized by significantly higher values of PS than are the athletes with a negative typological set, this holding true during all 2013 sporting events.

Identified trends may serve as possible predictors of the competitive success of athletes. A good illustration of this are the graphs in Figure 7, which show the averaged data for PS and performance success level at the 2013 international competitions for the top 11 athletes of the Russian Cross-Country Skiing and Biathlon Paralympic Team. Competition results were calculated as average from all the places taken by the athlete during the year at competitions of the national and international level. This result was subtracted from the number of competitions (from 10 to 15 for different athletes). For example, athlete participated in 10 competitions and took 3 first, 2 second and 5 fourth places; (3+4+20)/10 = 2.7; Competition Rating is 10 - 2.7 = 7.3.

As can be seen from Figure 7, highly skilled athletes are characterized by high levels of PS index.

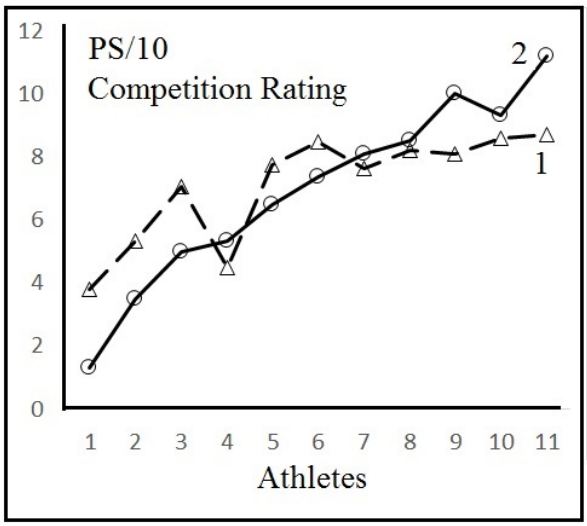

Figure 7. Averaged parameters of 11 Paralympic athletes based on the results of the 2013 season. 1 – Psychophysiological Stability (PS/10); 2 – performance success level.

5. Discussion

1) Knowledge of the properties of the nervous system of an athlete enables the prediction of her/his adaptability to training and competitive activities at high altitudes. The GDV "Bio-Well" device used in the study yields a sufficiently accurate estimation of the parameters of the psychophysiological state of athletes.

2) PS data reflect the process of psychophysiological adaptation of athletes to high altitudes and can serve as a prediction factor for evaluating the athletes' competitive success: a high PS parameter serve as indicator and reflect the level of the psychophysiological readiness of athlete at competitions. This conclusion was supported by numerous successful performances of athletes who consistently exhibited high PS level at important Russian and international competitions.

3) We may distinguish a typological set of the properties of the nervous system (which can be dubbed 'positive') which correlates with higher levels of adaptation to training and competition burdens at high altitudes.

4) The adaptation capabilities of skiers and biathletes increased after repeated training at high altitudes, indicating the need for multiple trips to the alpine training camps when preparing for important high-altitude competitions.

6. Conclusion

Monitoring of athletes' activity for a long time allowed creating the optimal training process and preparing athletes for completions in the peak of their adaptation, physical and psychological readiness. The best indication was successful performance of this team at Paralympic Winter Games Sochi-2014. Athletes on Russia Paralympic Team achieved commendable results in biathlon: Gold – 7, Silver – 5,

Bronze – 3, as well as in skiing: Gold – 10, Silver – 3, Bronze - 6. These are remarkable results, which was achieved by combining efforts of coachers, psychologists and scientists.

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