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Case Study

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Evaluation of the Effectiveness of Restoring Balance Function in Military Personnel with Lower Limb Amputations: A Clinical Case

Kalnysh VV[1]*, Serheta IV[2], Pashkovskyi SM[3], Bohush HL[2,3], Koval NV[2,3], Tymchushyn TP[2,3] and Anhelska VYu[2,3]

[1]*Ukrainian Military Medical Academy, Kyiv, Ukraine*

[2]*National Pirogov Memorial Medical University, Vinnitsya, Ukraine*

[3]*Military Medical Clinical Center of the Central Region, Vinnitsya, Ukraine*

***Corresponding author:** Ukrainian Military Medical Academy, Kyiv, Ukraine

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Introduction

In the conditions of a full-scale war unleashed by the Russian Federation, the number of people with limb amputations is growing every day. Thus, Ukrainian servicemen need high-quality medical care, rehabilitation, and prosthetics. Of course, a lost limb cannot be restored, but it is possible to return the patient the ability to walk, run, and live a full life using a rehabilitation aid. According to the Ukrainian independent news agency [1], about 10% of medical casualties among military personnel received serious injuries and traumas that required amputation of limbs. Amputation of a lower limb is a serious test for the body, which significantly affects motor activity and a sense of balance. However, thanks to modern rehabilitation methods, many patients can successfully restore lost functions and lead an active lifestyle. Lower limb amputation patients may have an unstable gait, which negatively affects their balance [2]. The loss of a lower limb results in a change in the body's center of mass (it shifts, making it difficult to maintain balance), impaired proprioception (receptors in the foot that are responsible for sensing the body's position in space are absent), and muscle weakness (muscles that provide stability may weaken due to prolonged immobilization or lack of physical activity), which affects balance function.

When the prosthesis is manufactured, the stage of prosthetic rehabilitation and adaptation to its use begins. At the stage of getting used to the prosthesis used, the motor skills of the amputated limb are restored. This allows for increased compensatory adaptation, the capabilities of which are largely determined by the strength and endurance of the muscular system. A multidisciplinary rehabilitation team draws up an individual rehabilitation plan for the patient, monitors the rehabilitation process and monitors the effectiveness of the intervention. One of the main tasks of such a rehabilitation team is to obtain reliable information on the success of the patient's habituation to wearing a prosthesis. That is why one of the powerful methods for assessing success is the use of a stabilographic platform. A stabilographic platform is a special device that allows you to measure and analyze the slightest body vibrations in a standing position. Using sensors, the platform records the shift of the center of gravity, which makes it possible to assess the level of a person's balance. Using a stabilographic platform in the rehabilitation of patients with lower limb amputations, it is possible to conduct an objective assessment of the restoration of balance function (the platform allows you to obtain accurate quantitative indicators of balance disorders, which is important for developing an individual rehabilitation plan), monitor progress (regular measurements on the platform allow you to track the dynamics of the restoration of balance function and the effectiveness of rehabilitation measures), as well as study the effectiveness of various rehabilitation methods (comparing the results of measurements before and after the application of different methods allows you to determine the most effective approaches). With the use of such devices, it is also possi-

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ble to study static, dynamic and post-rotational aspects of balance. Thus, obtaining information on the productivity of the patient's habituation to wearing a prosthesis can be achieved through the use of a stabilographic platform, which will improve the course of adaptation and restoration of the patient's movements. The development of technology for rationalizing the rehabilitation process of wounded military personnel is an urgent task, especially in war conditions, when there is a significant increase in the number of people who need such assistance.

Materials and Methods

The examinations were performed using an active medical device «Device for the study of vestibular functions «STABILIS» TU U 26.6. 37366104-002:2020» with the «StabiliS» software package version v2.00» [3]. It is known that the balance function is provided by the combined action of a number of systems: vestibular, visual, somatosensory. But it is generally accepted that the vestibular contribution to the implementation of the balance function is the most significant. Under the conditions of exclusion or leveling of alternative systems to the vestibular analyzer, the balance function is implemented almost exclusively at the expense of the vestibular analyzer [4]. Therefore, the studies were performed separately in the position with open and closed eyes. For the analysis, classical stabilometric parameters were used, as well as parameters characterizing the frequency spectrum of oscillations of the center of pressure in the frontal and sagittal planes. During the stabilographic examination of military personnel, in particular, the following indicators were recorded: Length – the length of the trajectory of oscillations of the center of pressure, AvgSpeed – the average speed of movement of the center of pressure, KFR – an indicator of the quality of the balance function [5,6]. The choice of the KFR parameter is not accidental, since it is the most stable integral indicator of the body's stability [6]. Statistical analysis of data was performed using methods of variational and nonparametric statistics, as well as correlation analysis of the STATISTICA 13.3 software package (license AXA905I924220FAACD-N).

Results

The development of a patient recovery technology after preparing him to wear a prosthesis consists of several stages, namely:

1) initial assessment of balance function;
2) periodic training of balance recovery using feedback;
3) periodic assessment of balance function in order to make corrections to the recovery process of military personnel.

A key feature of each of the above stages is the assessment of the balance function, which provides information about the state of the system supporting this function by measuring the shift of the patient's center of balance with open (under the control of the visual system and consciousness) and closed (the control of the vestibular apparatus and cerebellum prevails) eyes. Given that the loss of a limb leads to a radical shift in the center of pressure and its support mechanisms, it should be noted that getting used to using a prosthesis adds a number of difficulties for the patient, related not only to the dynamics of wound healing and getting used to using the prosthesis, but also to the process of learning to use this prosthesis in different conditions of everyday life. These problems gradually decrease as a result of training and restoring the patient's physical condition.

A sensitive and painless method for the patient is to use a stabilographic platform, which has shown its capabilities in assessing the physical condition of unmanned aerial system operators [7], as well as in other cases where there is a need for an emergency analysis of the quality of the posture support system under the influence of various conditions and life circumstances. The procedure for assessing the patient's recovery is not complicated, takes a short time and does not require the assistance of highly qualified specialists. The patient is placed on the upper support surface of the device in a vertical position and remains in this position for 5 minutes (2,5 minutes in the position with open and closed eyes, respectively). The processed signal from the sensors is sent to a personal computer, where special software calculates the relative coordinates of the point of application of the resultant force (the total center of pressure) acting from the side of the examined person on the support surface of the device, and also records and displays the change in the coordinates of the total center of pressure during the study.

It should be noted here that the change in the quality of any training is described by the so-called «learning curve». Its shape approaches a logistic curve and depends on many factors, in particular, the patient's physical condition, strong or weak pain during the test or their absence, success in mastering the use of the prosthesis, etc. Reaching the horizontal part of this curve may indicate success in this mastery. At the same time, it should be emphasized that the shape of the «learning curve» depends quite strongly on the complexity of the task of maintaining a vertical position for the patient. The more complex the task, the longer the period of time will be required for the «learning curve» to reach the horizontal part. In addition, in the process of getting used to the prosthesis, the patient may have periods of regression in the quality of maintaining a vertical position, etc. All these effects will be clearly manifested in the dynamics of the patient's recovery during periodic assessment of his condition. The patient examined at the Military Medical Clinical Center of the Central Region was a 37-year-old serviceman whose lower limb was amputated at the level of the lower third of the left thigh. After treatment and adaptation to the prosthesis, classical stabilometric parameters, as well as parameters characterizing the frequency spectrum of the center of pressure oscillations in the frontal and sagittal planes, were recorded every Monday for 5 consecutive weeks at approximately the same time. The results of five consecutive measurements of the results are shown in Figures 1-3. The length of the trajectory of the center of pressure oscillations is shown in Figure 1.

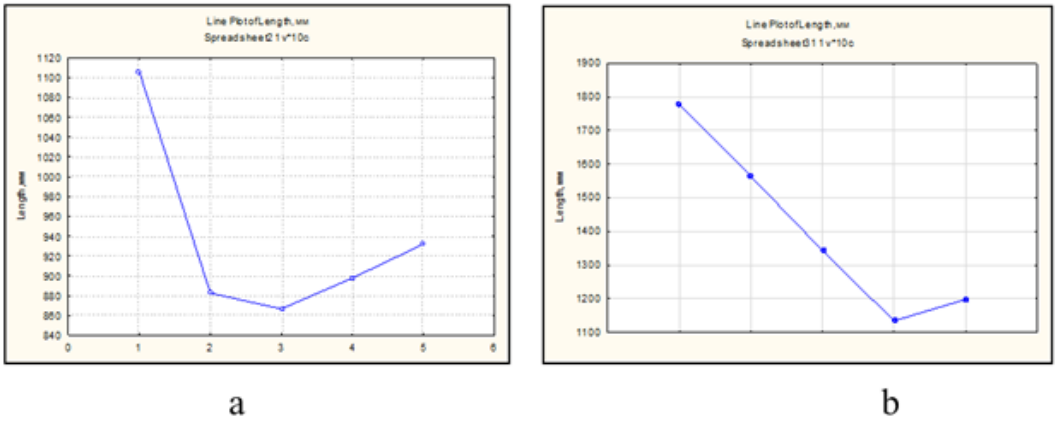

Figure 1: The length of the trajectory of oscillations of the center of pressure in the position with open (a) and closed (b) eyes.

Comparison of the figures in the position with open and closed eyes leads to several conclusions. First, there is a clearly visible difference between the presented curves, which can be explained by the influence of higher levels of brain control, including the regulatory role of the visual system. Second, the feedback provided by the visual system significantly accelerates the patient's success in maintaining an upright position. Already in the second measurement, a significant restoration of the function of equilibrium and balance of the body and a transition to constant support of this parameter are observed. Third, a decrease in the influence of higher levels of control of maintaining an upright position leads to a significant increase in the amplitude of oscillations of the center of pressure and a slow improvement in the levels of this indicator. The dynamics of changes in the average velocity of movement of the center of pressure in the analyzed patient is presented in Figure 2.

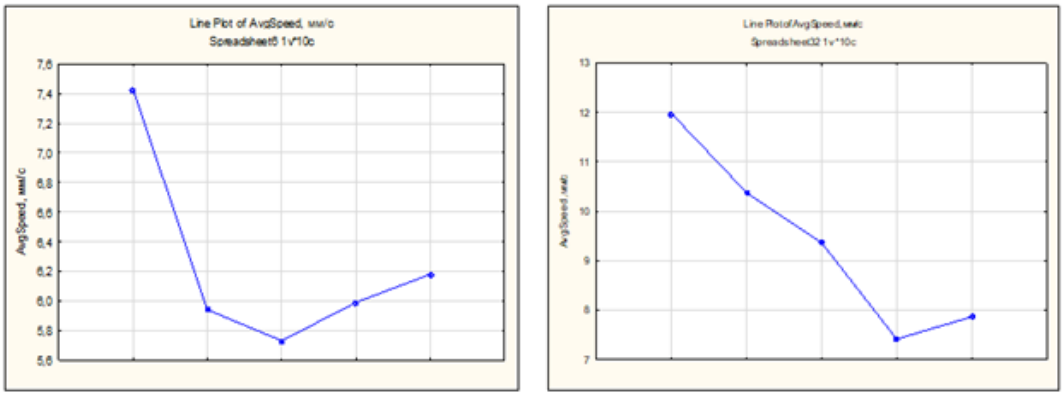

Figure 2: Average velocity of movement of the center of pressure in the position with open (a) and closed (b) eyes.

The change in the levels of the average velocity of the center of pressure movement in the position with open and closed eyes has the same pattern as in the previous case. Here it is necessary to emphasize one feature inherent in both described cases: after reaching the stabilization stage of the level of the analyzed parameter, its fluctuation towards deterioration is observed. This phenomenon indicates that the five-week period is insufficient for confident getting used to using the prosthesis. Further measurements can provide additional information about the success or slowdown of the process of restoring the function of the artificial limb. The dynamics of transformation of the quality of the patient's balance function is presented in Figure 3.

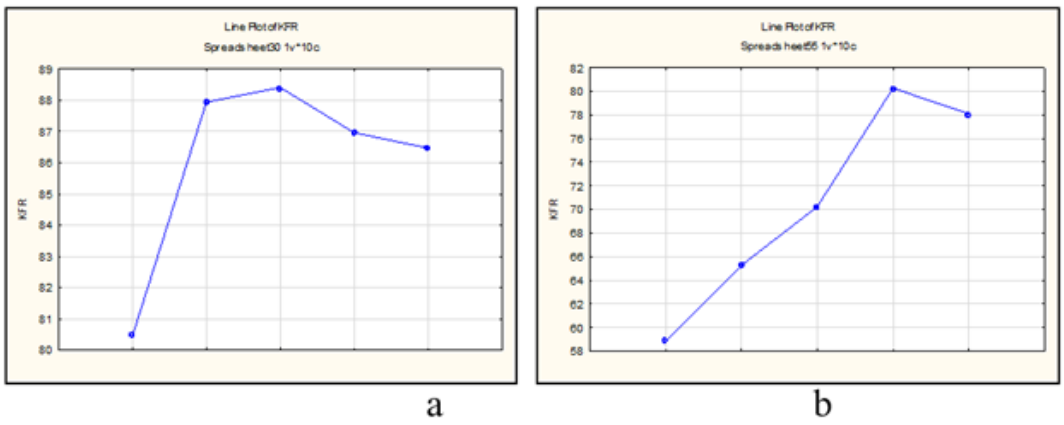

Figure 3: Quality of balance function in the position with open (a) and closed (b) eyes.

The form of the obtained «learning curve» in the dynamics of adaptation to the use of the prosthesis according to the quality indicator of the balance function is basically no different from the already given cases of improving its use according to the other given parameters. It is noteworthy that the gradual steps of success in using the prosthesis in this patient are homochronous in nature, that is, all of the given indicators synchronously and simultaneously change their parameters during the training process. This may indicate the positive nature of the recovery process in this patient. At the same time, it should be emphasized that the shape of the «learning curve» depends quite strongly on the complexity of the task of maintaining a vertical position for the patient. The more complex the task, the longer the period will be required for the «learning curve» to reach the horizontal part. In addition, in the process of getting used to the prosthesis, the patient may have periods of regression in the quality of maintaining a vertical position, etc. All these effects will be clearly manifested in the dynamics of the patient's recovery during periodic assessment of his condition. In other cases, the results of improving the quality of maintaining a vertical position will not be the same when analyzing the informative indicators of the stabilogram. The revealed phenomenon of heterochrony in the process of getting used to the use of the prosthesis will depend on the speed of recovery of lost functions by all links of the posture maintenance system: central, peripheral. Therefore, analysis of the shape of the «learning curve», which in this case can be called a "recovery curve", will provide more complete information about the recovery of functions of individual links of the posture maintenance system and the use of the prosthesis. This analysis can provide information about the predominant shift of the patient's center of gravity in a certain direction or indicate the predominant plane of its oscillations, which can be used to organize special training aimed at correcting the identified defects.

In the process of monitoring the effectiveness of rehabilitation care at different stages of mastering the use of the prosthesis, it is advisable to use the patient's recovery progress indicator according to the formula:

$$PR=(P_{current}-P_{initial})/(P_{target}-P_{initial})\times 100\%,$$

where:

$P_{initial}$ - initial indicator, the value of the indicator at the beginning of rehabilitation assistance;

P_{target} - target indicator, the desired (planned) value of the indicator that needs to be achieved at the end of the rehabilitation period;

$P_{current}$ - current indicator, the value of the indicator at a specific point in time of control or rehabilitation stage.

This formula shows what percentage of the required progress has been achieved at a specific point in time. An example of the corresponding calculation can be given. Let's assume that the quality indicator of the balance function with open eyes at the beginning of rehabilitation is 80%, and the target level of the balance function quality that we want to achieve is 91%. At the time of assessment, the patient has a score of 88%. Then the calculation will be as follows:

$$PR=(88-80)/(91-80)\times 100\%=73\%.$$

Thus, after a week of training, the patient achieved 73% of the planned progress.

Of course, the presented calculations are approximate, but they will help physical and rehabilitation medicine doctors, and possibly the patient, navigate the recovery process to improve it and increase the patient's motivation level. To determine the target level of rehabilitation, it is advisable to present the average levels of the discussed indicators for a group of 74 healthy military personnel aged 30-39 (Table 1).

Table 1: Average levels of stabilogram indicators in healthy military personnel in the position with open and closed eyes.

Stabilogram Indicators	Open Eyes	Eyes Closed
Length, mm	765,56±25,77	1208,057±1,51
AvgSpeed, mm/s	5,11±0,17	8,131±0,20
KFR, %	90,57±0,74	77,138±4,55

Systematic provision of information on the parameters of success or regression in the process of providing rehabilitation care will allow optimizing its organization and, in the case of periodic provision of this data to the patient with appropriate explanations from specialists, will allow forming adequate motivation to accelerate recovery.

Discussion

This work has made the first important step towards introducing quantitative system indicators into the rehabilitation process for its improvement. With the acquisition of more material, it will be possible to obtain information about the influence of individual links of the vertical posture support system on the process of getting used to using the prosthesis with the aim of its improvement.

Conclusions

1) An approach is proposed to assess the quality of habituation when using prostheses in military personnel who are inpatients in a rehabilitation department after limb amputation after participating in combat operations.

2) A methodology for calculating the quality indicators of the use of prostheses in the rehabilitation process is substantiated to optimize the organization of this process and increase the patient's motivation for the fastest possible recovery.

Acknowledgments

None.

Conflicts of Interest

None.

References

1. *https://www.unian.ua/war/viyna-v-ukrajini-vid-20-do-50-tisyach-ukrajinciv-perezhili-amputaciyu-wsj-12348438.html.*
2. Jeneau P, Baddour N, Burger H, Lemaire ED (2024) Balance confidence classification in heople with a lower limb amputation using six minute walk test sensor signals. PLOT Digit Health 3(8): e0000570.
3. Kochyna ML, Kaminsky AA (2012) Hardware and software complex for the study of the static dynamic stability of a person. Appl Rradio electron 11(1): 120-124.
4. Kompaniyets OA (2022) Static balance: clinical aspects and professional selection of servicemen [monograph]. Kamyanets-Podilskyi: Ruta Printing house LLC 288 p. ISBN 978-617-8221-16-4.
5. Sliva SS (2025) Domestic computer stabilography: endineeng standards, functional capabilities, and fields of application. BioMed Eng 39(1): 31-34.
6. Sologubov EG, Yavorskii AB, Cobrin VI, Nemkova SA, Sinel'nikova AN (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 34(3): 138-143.
7. Kalnysh VV, Trinka IS, Pashkovskyi SM, Koval NV, Bohush HL, et al. (2024) Express Assessment of the Physical Condition of Operators of Unmanned Aircraft Systems. Am J Biomed Sci & Res 22(1): 199-201.