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Kinesiological models of the neuromuscular system readaptation in mature women after prolonged hypokinesia

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Abstract

Purpose
To study the peculiarities of adaptive and compensatory reactions in mature women after prolonged hypokinesia using various kinesiological models of the neuromuscular system readaptation.

Material and methods
52 women of mature age (39-46 years) after long-term (6-7 years) hypokinesia took part in the study. Group A used a kinesiological model based on free weight exercises with changes in kinematic and dynamic characteristics. Group B used a model based on machine exercises. The following methods were used to monitor adaptation processes: bioelectrical impedance analysis, anthropometry, testing of strength capabilities, biochemical blood analysis (cortisol and creatinine concentration).

Results
The dynamics of the studied indicators differed significantly between the groups using the proposed kinesiological models for 12 weeks. Thus, the fat-free and body cell mass indicators were 5 times higher in group A women compared to group B participants. The body fat mass decreased by 5 times in group A participants. The circumference measurements reduced in all participants, but in group A the rate of change was 1.8 times faster. The level of strength growth was almost the same in all study participants; it fluctuated within 10-25% compared to the initial data. The cortisol concentration in the blood serum increased only in group B during all stages of control. At the end of the research, the cortisol level did not change in response to stress in the women of group A, which indicates increasing of their resistance level. The basal level of creatinine grew by 4% in group A women after 12 weeks of training, but it did not change in group B participants. These changes indicate an accelerated growth of muscle mass in group A women.

Conclusions
Pronounced adaptive changes occurred in women of mature age after prolonged hypokinesia in case of using the kinesiological model of the neuromuscular system readaptation with free weight exercises. Applying this model helps to increase the functional capabilities of the body, to strengthen the level of resistance to a stress stimulus, and to improve the morphometric parameters of the body.

Key words: adaptation, mature women, stress stimulus, kinesiological model, neuromuscular system

Анотація

Андрій Чернозуб, Манолакі В’ячеслав, Володимир Потоп, Олексій Худий, Сергій Козін, Вікторія Бокатуєва, Аліна Кізілова, Маріус Стенеску, Олівія Кармен Тімнеа. Кінезіологічні моделі реадаптації нервово-м’язової системи жінок зрілого віку після тривалої гіпокінезії

Мета

Вивчити особливості адаптаційно-компенсаторних реакцій у жінок зрілого віку після тривалої гіпокінезії використовуючи різні кінезіологічні моделі реадаптації нервово-м’язової системи.

Матеріал і методи

В дослідженні взяли участь 52 жінки зрілого віку (39-46 років) після тривалої (6-7 років) гіпокінезії. Група А використовувала кінезіологічну модель основану на вправи з власною масою тіла зі зміною кінематичних та динамічних характеристик. Група Б використовували модель в основі якої були вправи на тренажерах. Для контролю за процесами адаптації використовували наступні методи: біоімпедансометрія, антропометрія, тестування силових можливостей, біохімічний аналіз крові (концентрації кортизолу та креатиніну).

Результати

Виявлено, що динаміка досліджуваних показників за 12 тижнів використання запропонованих кінезіологічних моделей суттєво відрізняється між групами. Так, зростання показників безжирової та активної маси тіла у жінок групи А в 5 раз вище порівняно з опонентами. Рівень зниження показника жирової маси тіла в 5 раз вищий саме в учасників групи А. Обвідні розміри тіла демонструють зниження у всіх учасників, але в групі А в 1,8 рази більш прискорені темпи змін. Встановлено, що рівень зростання силових можливостей між учасниками обох груп майже не відрізняються та коливаються в межах 10-25% порівняно з вихідними даними. Підвищення концентрація кортизолу в крові на стресовий подразник протягом всіх етапів контролю виявлено лише в групі Б. У жінок групи А в кінці досліджень рівень кортизолу не змінювався у відповідь на навантаження, що свідчить про підвищення резистентності. Базальний рівень креатиніну у осіб групи А зростає на 4% через 12 тижнів занять, а у представників іншої групи не змінюється. Відповідні зміни свідчать про прискорене зростання м’язової маси у жінок групи А.

Висновки

У жінок зрілого віку після тривалої гіпокінезії виражені адаптаційні зміни в організмі відбуваються в умовах використання в кінезіологічній моделі з реадаптації нервово-м’язової системи комплексу вправ з власною масою тіла. Використання даної моделі сприяє підвищенню функціональних можливостей організму, рівня резистентності до стресового подразника, покращенню морфометричних параметрів тіла.

Ключові слова: адаптація, жінки зрілого віку, стресовий подразник, кінезіологічна модель, нервово-м’язова система

Аннотация

Андрей Чернозуб, Манолаки Вячеслав, Владимир Потоп, Алексей Худый, Сергей Козин, Виктория Бокатуева, Алина Кизилова, Мариус Стэнеску, Оливия Кармен Тимнеа. Кинезиологические модели реадаптации нервно-мышечной системы женщин зрелого возраста после продолжительной гипокинезии

Цель

Изучить особенности адаптационно-компенсаторных реакций у женщин зрелого возраста после длительной гипокинезии, используя различные кинезиологические модели реадаптации нервно-мышечной системы.

Материал и методы

В исследовании приняли участие 52 женщины зрелого возраста (39-46 лет) после продолжительной (6-7 лет) гипокинезии. Группа А использовала кинезиологическую модель основанную на упражнениях с собственной массой тела с изменением кинематических и динамических характеристик. Группа Б использовала модель, в основе которой были упражнения на тренажерах. Для контроля за процессами адаптации использовали следующие методы: биоимпедансометрия, антропометрия, тестирование силовых возможностей, биохимический анализ крови (концентрация кортизола и креатинина).

Результаты

Выявлено, что динамика изучаемых показателей за 12 недель использования предложенных кинезиологических моделей существенно отличается между группами. Так, рост показателей безжировой и активной массы тела у женщин группы А в 5 раз выше по сравнению с оппонентами. Уровень снижения показателя жировой массы тела в 5 раз выше именно у участников группы А. Охватные размеры тела демонстрируют понижение у всех участников, но в группе А в 1,8 раза более ускорены темпы изменений. Установлено, что уровень роста силовых возможностей между участниками обеих групп почти не отличается и колеблется в пределах 10-25% по сравнению с исходными данными. Повышение концентрации кортизола в крови на стрессовый раздражитель на протяжении всех этапов контроля выявлено только в группе Б. У женщин группы А в конце исследований уровень кортизола не изменялся в ответ на нагрузку, что свидетельствует о повышении резистентности. Базальный уровень креатинина у лиц группы А увеличился на 4% через 12 недель занятий, а у представителей другой группы не меняется. Соответствующие изменения свидетельствуют об ускоренном росте мышечной массы у женщин группы А.

Выводы

У женщин зрелого возраста после продолжительной гипокинезии выраженные адаптационные изменения в организме происходят в условиях использования в кинезиологической модели по реадаптации нервно-мышечной системы комплекса упражнений с собственной массой тела. Использование данной модели способствует повышению функциональных возможностей организма, уровню резистентности к стрессовому раздражителю, улучшению морфометрических параметров тела.

Ключевые слова: адаптация, женщины зрелого возраста, стрессовый раздражитель, кинезиологическая модель, нервно-мышечная система

Introduction

One of the main problems of human life in the modern realities of the society development is counteraction to external stressful stimuli by optimizing the work of the body systems. The issue of improving adaptation processes due to increasing body reserves and maintaining homeostasis as a whole is integral. This problem has become especially acute in recent decades, which is justified by the rapid increase in the number of social and economic stimuli, the general decrease in the level of physical development of the population, and the need to constantly increase the level of the body resistance to stress factors of the external influence [1–3].

An important aspect when studying the mechanisms of body adaptation to stressful situations of various character is the study of the reverse process - disadaptation. The processes of disadaptation arise as a result of the lack of adaptive reactions to the stress factor, and lead to a decreased activity of some body systems. Disadaptation of the neuromuscular system occurs as a consequence of a rapid decrease in the level of motor activity. The main factors are sudden changes in the level of external stimuli influence or pathological changes in the body [4]. These changes in a person's life lead to a state of hypokinesia. This problem is especially acute in cases of malfunctioning of some parts of the neuromuscular system due to manifestations of pathological conditions associated with a stroke, corona virus disease [5, 6].

An urgent issue of modern kinesiology is the search for effective ways of using the results of scientific research in biomechanics and physiology to counter the processes of disadaptation. The problem of studying the mechanisms of restoring the capabilities of body systems after a long period of disadaptation caused by various factors is a priority task for a number of scientists [7–9]. The main issue for determining the periodization and spectrum of methods to use for the neuromuscular system readaptation is to conduct a detailed analysis of the functional and physical state of a person after a period of disadaptation. Applying biochemical and physiological research methods to assess the nature of adaptive and compensatory reactions to a stressful stimulus allows to reveal the degree of its adequacy to the functional capabilities of the body. Determining the body adaptive reserves and their effectiveness against the stimulus is one of the key criteria for monitoring functional capabilities. This is especially relevant at the initial stage of the neuromuscular system readaptation. A detailed assessment of the neuromuscular system state using modern medical and biological diagnostic methods enables clear definition of activities for developing an integrated system of readaptation. At the current stage of studying readaptation, there arises a proposition of researching the effectiveness of using different volume and intensity loads and exercises [2, 10, 11].

Creating an optimal stressful physical stimulus to increase the adaptive reserves of the human body in a state of hypokinesia is one of the practical directions of kinesiology specialists [12–14]. Solving this issue requires an integrated approach due to the combination of modern research in power fitness, sports physiology, biochemistry of motor activity, diagnostics of body systems, dynamic anatomy [2, 10, 15]. A comprehensive approach to the process of modeling the effective activities for the neuromuscular system readaptation requires substantiating the correspondence of the external stimulus to the initial level of the body adaptive reserves [16, 17]. Using innovative complexes of physical exercises with different kinematics, methods of load correction depending on the features of adaptive and compensatory reactions to the stimulus, assessment of the functional state and the neuromuscular system state are the basis for modeling.

In the available literature, there are various directions of using exercises in kinesiotherapy to solve problems with the musculoskeletal system [3, 4, 7, 11]. However, practicing only various exercises with standard load parameters may not always correspond to the body resistance level and contribute to readaptation processes. The lack of using physiological methods for diagnosing the primary level of the functional state makes it difficult to determine the optimal indicators of the load volume and intensity. The application of biochemical blood analysis to assess the level of energy supply of muscle activity and control of readaptation processes allows to clearly determine the mechanism of model correction [2, 10, 18, 19]. The development of an integral algorithm for the neuromuscular system readaptation after prolonged hypokinesia will give an opportunity to clearly define the optimal range of control methods and management mechanisms.

The purpose of the research is to study the peculiarities of adaptive and compensatory reactions in mature women after prolonged hypokinesia using various kinesiological models of the neuromuscular system readaptation.

Material and methods

Participants

52 women in the second period of maturity, living in Kyiv, Ukraine, took part in the study. The age of these women was 39-46 years. The research participants have been in a state of hypokinesia during the last 6-7 years. The participants were randomly divided into two groups: A and B. Group A participants used the kinesiological model for the neuromuscular system readaptation with free weight exercises with changes in kinematic and dynamic characteristics (model A). Group B participants took up a kinesiological model based on machine exercises (model B). The proposed kinesiological models of the neuromuscular system readaptation of mature women after prolonged hypokinesia are presented in Table 1

The algorithm, structure and methods of the study were approved by the ethical committee for biomedical research of Lesya Ukrainka Volyn National University in accordance with the ethical standards of the Declaration of Helsinki. Participants gave written informed consent for the research in accordance with the recommendations of the biomedical research ethics committees [20].

Table 1

Kinesiological models of the neuromuscular system readaptation
of mature women after prolonged hypokinesia

Model	Description
Model A	– The basis of this model is using free weight exercises with a complete change in the kinematic, dynamic and rhythmic characteristics of the technique. In terms of the biomechanics of movements, these exercises are very similar to machine exercises, but require the involvement of almost 30% more muscle groups during work. – The training duration is 30-35 minutes; each set lasts until the complete fatigue in the involved muscles (performance technique deteriorates); the duration of rest between sets is 30 seconds; the duration of the concentric phase of the movement is 3 s and the eccentric phase is 6 s; exercises are performed with partial amplitude (85-90% of 1 RM) with fixation at the peak point; the number of exercises in one training is not more than 6-7; the number of sets per exercise ranges from 4 to 5. – For an additional increase in muscle tension, the duration of the eccentric phase of the movement increases (9–11 s); the technique of performing the exercise changes due to the amplitude and position of the body in space; there is a decrease in the duration of rest intervals between sets. The level of exercise complexity and their variability is constantly changing. – Control over readaptation processes occurs due to the assessment of the dynamics of morphofunctional indicators and the nature of adaptive and compensatory reactions to a stimulus at various stages of research
Model B	– The model is based on using machine exercises; exercise technique meets the requirements of power fitness; no more than 2-3 muscle groups are involved during a single exercise; the principle of "premature fatigue" is used. – The training duration is 60-65 minutes; the amount of load is 40-45% of 1 RM; the set duration is about 90 seconds; rest intervals between sets ranges from 70-90 seconds; exercises are performed with full amplitude without fixation at the peak point; the number of sets is 3-4 with 25 repetitions each; the total number of exercises during the training varies from 8 to 9. – Additionally, the amount of encumbrance is adjusted (increased by 12–17%) if necessary; the sequence and frequency of using exercises is changed. In some cases, rest intervals are reduced to 20%. – Control over readaptation processes is held by assessing the dynamics of morphofunctional indicators and the nature of adaptive and compensatory reactions to the stimulus at various stages of the study

Body composition

Body composition parameters were determined with the help of bio electrical impedance analysis (BIA) and further computer processing of the data. These parameters were recorded at the beginning and during the next 12 weeks of the study with a periodicity of 30 days. BIA allows to determine a large number of parameters, but during this research we controlled the indicators of fat-free mass (FFM, kg), body fat mass (BF, %), body cell mass (BCM, kg) of the participants. The diagnostic computerized hardware and software complex KM-AR-01 of the "Diamond – AST" configuration (VYUSK. 941118.001 PE) was used to determine the studied indicators of body composition.

Circumferential body measurements

Circumferential body (shoulder, forearm, thigh, shin, waist) measurements were made using a centimeter tape following the generally accepted methodology. Controlled indicators were measured at the beginning and during 12 weeks of the study with a frequency of 45 days.

Strength measurements

The control over the strength development took place during free weight and machine exercises which are completely different in structure, but identical movements in terms of biomechanics. The development of maximum strength (1 RM) occurred during machine exercises in participants of group B. The development of strength endurance was controlled with the help of the load volume (number of repetitions until complete muscle fatigue in 4 sets) during free weight exercises in group A women. It is 4 sets that are used during the training to fully load a muscle group. The strength indicators assessment was conducted in three stages: at the beginning of the study and after every six weeks. To assess strength endurance the following free weight exercises were used: squats with the gravity center shift, hyperextension on a straight bench, inclined push-up standing from the foothold, lifting legs lying with support on the elbows, lifting the trunk lying (twisting). Controlling the 1 RM indicator development, these machine exercises were used: leg press on the block, leg extension in the knee joint on the block, head pull on the block, arm extension on the block.

Biochemical blood parameters

The creatinine concentration in the blood serum was checked by means of the kinetic method on the equipment of "High Technology Inc" (USA) with a set of reagents PRESTIGE 24i. The cortisol concentration in blood serum was determined by enzyme immunoassay using the SteroidIFA-testosterone reagent kit on Alcor Bio equipment. The blood sampling procedure was performed according to the general requirements of biomedical research. The changes in biochemical blood parameters were controlled at the beginning of the study and after 12 weeks of training at rest (before the load) and at the end of the training session.

Research algorithm

Figure 1 presents the integral algorithm of the neuromuscular system readaptation in mature women after prolonged hypokinesia which clearly reflects the sequential system of the main factors interaction in kinesiology. The analysis of this algorithm enables a reasonable determining of ways to optimize the structure of kinesiological model, taking into account the individual state of hypokinesia. Directions for correcting the structure of physical exercises, searching for both safe and effective strength load parameters are revealed. These changes will contribute not only to increasing the functional body capabilities in the shortest possible time, but also to the processes of the neuromuscular system readaptation.

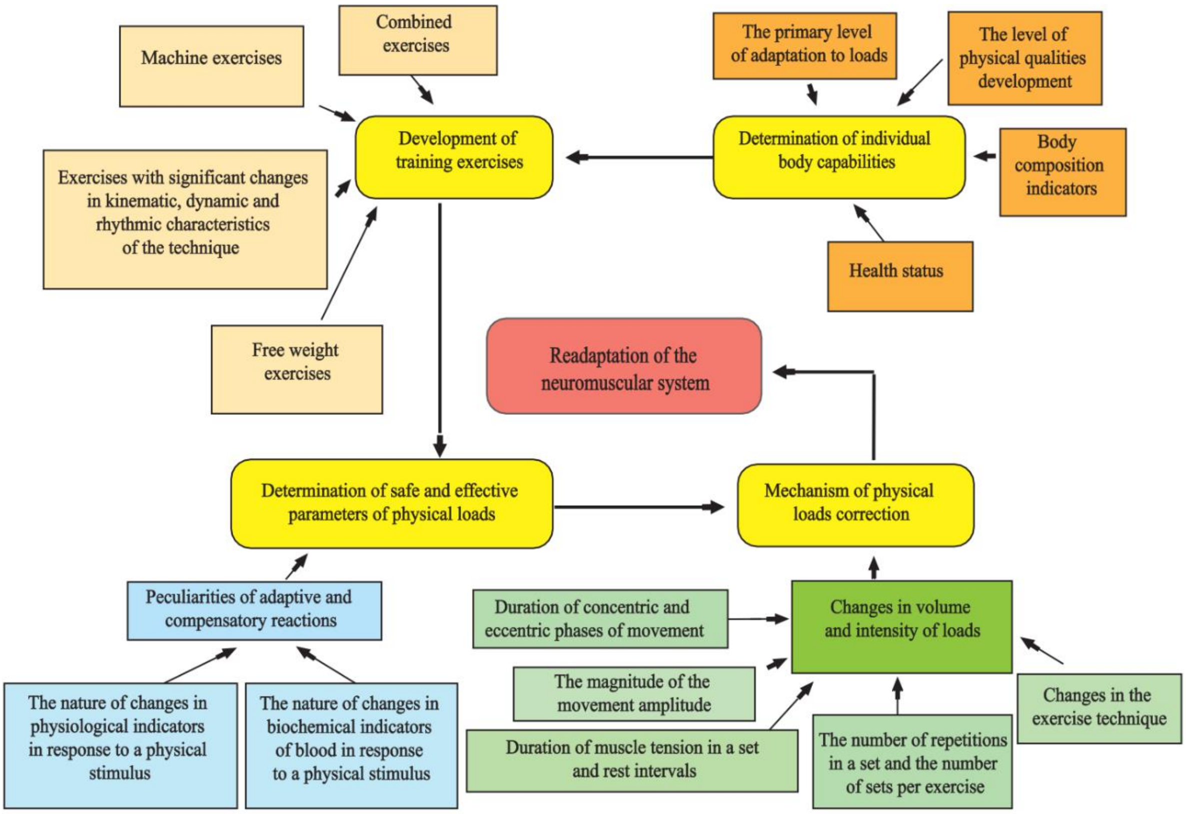

Fig. 1. The scheme of the integral algorithm of the neuromuscular system readaptation in mature women after prolonged hypokinesia

Statistical analysis

Statistical analysis of the research results was performed using the IBM *SPSS*Statistics 26 program package (StatSoftInc., USA). Median, lower and upper quartiles, interquartile range (IQR) were determined. Mann-Whitney test was used for testing whether samples originate from the same distribution. Friedman's two-way analysis of variance by ranks was used to compare indicators of the same sample of subjects during the control period. Kendall's W (the Kendall's coefficient of concordance) is an effect size index for Friedman test. The Kolmogorov-Smirnov test was used to determine the normal distribution. The G-Power 3.1.96 program was used to calculate statistical power (determining the smallest sample size for the study). The sample size was evaluated using statistical tests: Wilcoxon signet-rank test (one sample case); ANOVA: Repeated measures, between factors.

Results

Body composition

Table 2 shows the results of monitoring the body composition indicators of the participants of both groups: fat-free body mass, fat body mass, active body mass. Features of changes in their parameters were recorded during 12 weeks of the study in the conditions of using kinesiological models of different structure and load level.

Table 2

BIA indicators changes in the examined groups during the study,
(median and interquartile range (IQR), n=52

Groups	Term of observation, weeks				χ^2, p df=3
	Initial data	4	8	12	
Fat free mass, kg					
A	49.43 (12.37) U=281, p=0.38	50.26 (12.81) 1.7%^{1*}	51,51 (13.05) 2.5%^{1*}	52.01 (11.83) 1.0%^{1}, 5.2%^{2*}	χ^2=8.53* W=0.10*
B	48.29 (12.14) U=281, p=0,38	47,91 (12.03) -0.8%^{1}	48.51 (11.89) 1.2%^{1}	48.59 (9.75) 0.2%^{1}, 0.6%^{2}	χ^2=6.34 W=0.07
Body fat, %					
A	24.72 (7.25) U=273, p=0.22	24.56 (8.07) -0.2%^{1}	24.25 (7.75) -0.3%^{1}	23.02 (8.12) -1.2%^{1}, -1.7%^{2*}	χ^2=9.87* W=0.14*
B	25,1 (6.73) U=273, p=0.22	25.00 (5.88) -0.1%^{1}	24.96 (6.44) -0.04%^{1}	24.83 (7.05) -0.1%^{1}, -0.3%^{2}	χ^2=3.89 W=0.04
Body Cell Mass, kg					
A	31.56 (9.25) U=367, p=0.88	33.01 (9.92) 4.6%^{1*}	33.49 (7.75) 1.4%^{1*}	33.96 (7.50) 1.4%^{1*}, 7.6%^{2*}	χ^2=9.99* W=0.15*
B	31.33 (11.04) U=367, p=0.88	31.45 (8.93) 0.4%^{1}	31.59 (9.02) 0.4%^{1}	31.71 (8.75) 0.4%1, 1.2%^{2}	χ^2=7.08 W=0.09

Notes: ^{1} – difference (%) compared to previous results; ^{2} – difference (%) in comparison with the initial data; df is the number of degrees of freedom; U - Mann-Whitney test; χ^2 – Friedman's test; W is the Kendall's coefficient of concordance; * – p<0.05

The obtained results analysis showed that the studied indicators dynamics was significantly different between the groups during the research. Thus, group A women increased FFM by 5.2% (p<0.05) during 12 weeks. BCM indicator grew by 7.6% (p<0.05) in group A women compared to the initial data. Body fat lowered by 1.7% (p<0.05) in group A participants. The results of group B participants indicated no significant changes in all three controlled indicators of body composition during the entire study.

Circumferential body measurements

The changes in the circumferential measurements of the shoulder, forearm, thigh, shin, and waist in study participants during 12 weeks of research are represented in Table 3. We evaluated the dynamics of these indicators using two kinesiological models with free weight and machine exercises.

Table 3

The results of changes in the circumferential body measurements
in study participants during the research (median and interquartile range (IQR), n=52

Circumferential measurements, cm	Groups	Initial data	Term of observation, weeks		χ^2, p df=2
			6	12	
Shoulder	A	29.00 (5.75) U=298, p=0.46	28.75 (5.12) -0.9%^{1}	27.50 (4.63) -4.3%^{1*}, -5.2%^{2*}	χ^2=17.02* W=0.32*
	B	27.00 (6.12) U=298, p=0.46	27.50 (6.75) 1.9%^{1*}	27.00 (5.25) -1.9%^{1*}, -1.9%^{2*}	χ^2=15.57* W=0.30*
Forearm	A	24.00 (3.50) U=260, p=0.14	24.00 (3.63) 0.0%^{1}	23.50 (3.50) -2.1%^{1*}, -2.1%^{2*}	χ^2=20.97* W=0.40*
	B	22.5 (2.00) U=260, p=0.14	22.50 (2.38) 0.0%^{1*}	22.00 (3.25) -2.2%^{1*}, -2.2%^{2*}	χ^2=26.30* W=0.50*
Thigh	A	58.50 (6.50) U=375, p=0.49	57.25 (5.50) -2.1%^{1*}	55.75 (5.87) -2.6%^{1*}, -4.7%^{2*}	χ^2=35.01*** W=0.66***
	B	57.00 (6.25) U=375, p=0.49	57.00 (6.63) 0.0%^{1*}	55.00 (6.12) -3.5%^{1*}, -3.5%^{2*}	χ^2=24.07*** W=0.46***
Shin	A	37.00 (3.75)	36.00 (3.50)	36.00 (3.63)	χ^2=1.82

		U=296, p=0.43	-2.7%^{1*}	0.0%^{1}, -2.7%^{2*}	W=0.03
	B	35.00 (4.87) U=296, p=0.43	35.50 (5.13) 1.4%^{1}	36.00 (3.88) 1.4%1, 2.8%^{2*}	χ^2=0.63 W=0.01
Waist	A	77.50 (12.50) U=316, p=0.68	76.25 (13.00) -1.6%^{1*}	72.75 (12.63) -4.6%^{1*}, -6.1%^{2***}	χ^2=43.70*** W=0.84***
	B	75.50 (14.00) U=316, p=0.68	74.50 (12.78) -1.3%^{1*}	72.50 (13.08) -2.7%^{1*}, -4.0%^{2***}	χ^2=39.50*** W=0.76***

Notes: ^{1} – difference (%) compared to previous results; ^{2} – difference (%) in comparison with the initial data; df is the number of degrees of freedom; U - Mann-Whitney test; χ^2 – Friedman's test; W is the Kendall's coefficient of concordance; * – $p<0.05$

The study revealed significant changes in the controlled indicators at the end of the study compared to the initial measurements of mature age women of both groups. However, paying attention to the nature of these changes, a decrease in their value developed while applying the proposed kinesiological models. On average, the circumference body measurements of group A participants decreased by 4.2% ($p<0.05$) during 12 weeks of performing free weight exercises. In group B women using machine exercises, circumferential indicators lowered by 2.9% ($p<0.05$) compared to the initial data.

Strength measurements

Table 4 shows the results of changes in load volume (series of 4 sets) of group A participants performing free weight control exercises during the 12-week study. This indicator characterizes the peculiarities of the strength endurance development.

Table 4

Changes in the load volume (a series of 4 sets) of group A women performing free weight control exercises, (median and interquartile range (IQR), n=26

Free weight exercises, number of repetitions until full muscle fatigue	Initial data	Term of observation, weeks		χ^2, p df=2
		6	12	
Squats with the gravity center shift	42.00 (32.00)	61.00 (52.00) 45.2%^{1*}	101.00 (50.22) 65.6%^{1***}, 115.5%^{2***}	χ^2=29.00*** W=0.57***
Hyperextension on a straight bench	49.00 (20.50)	54.00 (29.50) 10.2%^{1*}	83.00 (28.65) 53.7%^{1***}, 69.4%^{2***}	χ^2=35.84*** W=0.68***
Inclined push-up standing from the foothold	40.00 (16.00)	54.00 (32.00) 35.0%^{1***}	65.00 (35.00) 20.4%^{1*}, 62.5%^{2***}	χ^2=40.73*** W=0.78***
Lifting legs lying with support on the elbows	39.00 (8.75)	57.00 (15.00) 46.1%^{1***}	74.00 (33.23) 29.8%^{1*}, 89.7%^{2***}	χ^2=43.37*** W=0.83***
Lifting the trunk lying (twisting)	44.00 (8.00)	51.00 (14.50) 15.9%^{1*}	70.00 (21.25) 37.2%^{1***}, 59.0%^{2***}	χ^2=36.78*** W=0.70***

Notes: ^{1} – difference (%) compared to previous results; ^{2} – difference (%) in comparison with the initial data; df is the number of degrees of freedom; χ^2 – Friedman's test; W is the Kendall's coefficient of concordance; * – $p<0.05$; *** – $p<0.001$

The control testing results indicated that performing free weight exercises in the kinesiological model with a complete change in kinematic characteristics contributed to the growth of strength endurance. Thus, the greatest increase in the studied indicator by 115.5% ($p<0.05$) was found during the exercise "squats with the gravity center shift" compared to the initial data. The smallest development of power endurance by 59.0% ($p<0.05$) was observed during the exercise "lifting the trunk lying" according to the results of the load volume indicator in 4 sets.

Table 5 presents the maximum strength (1 RM) development in group B women performing machine control exercises during the study.

Table 5

Changes in the maximum strength (1 RM) development in group B participants performing machine control exercises during the study, (median and interquartile range (IQR), n=26

Machine exercises, kg (1RM)	Initial data	Term of observation, weeks		χ^2, p df=2
		6	12	
Leg press on the block	40.00 (8.00)	48.00 (8.00) 20.0%^{1***}	50.00 (8.00) 4.1%^{1*}, 25.0%^{2***}	χ^2=46.26*** W=0.92***
Leg extension in the knee joint on the block	32.00 (6.50)	35.00 (8.00) 9.4%^{1*}	37.00 (6.50) 5.7%^{1*}, 15.6%^{2***}	χ^2=46.47*** W=0.92***
Head pull on the block	27.00 (5.00)	30.00 (2.00) 11.1%^{1*}	32.00 (2.00) 6.6%^{1*}, 18.5%^{2***}	χ^2=43.91*** W=0.87***
Arm extension on the block	15.00 (3.00)	16.00 (2.00) 6.7%^{1*}	16.50 (2.00) 3.1%^{1*}, 10.0%^{2*}	χ^2=18.42*** W=0.36***

Notes: ^{1} – difference (%) compared to previous results; ^{2} – difference (%) in comparison with the initial data; df is the number of degrees of freedom; χ^2 – Friedman's test; W is the Kendall's coefficient of concordance; * – p<0.05; *** – p<0.001

The studied indicators of the maximum strength development during the control exercises demonstrated positive dynamics at all stages of the study. The greatest increase in the 1 RM indicator by 25.0% (p<0.05) was observed during the exercise "leg press on the block" in group B women compared to the initial data. The smallest change in the maximum strength development by 10.0% (p<0.05) during 12 weeks of studies was found while performing the exercise "arm extension on the block".

Biochemical blood parameters

The results of changes in the cortisol concentration in the blood serum of both group participants using the proposed kinesiological models during 12-week research are shown in Figure 2.

At the beginning of the study, cortisol concentration in blood serum of group A women grew by 82.3% (p<0.05) compared to the state of rest. This hormone also increased in the blood serum of group B participants by 52.2% (p<0.05) in response to the stress stimulus. The obtained results did not go beyond the upper limits of the physiological norm, which indicates the load adequacy to the functional capabilities of women of both groups.

After 12 weeks of training there was an increase in the cortisol concentration by 46.9% (p<0.05) in the blood serum of group B women compared to the state of rest. At the end of studies this hormone did not change significantly in group A representatives in response to a stress stimulus. This fact indicates that group A women increased their level of resistance to such loads.

Figure 3 depicts the results of changes in creatinine concentration in the blood serum of both group participants in response to the training load applying kinesiological models with different structure during 12 weeks of the study.

The initial measurements indicated that the creatinine concentration in the blood serum of group A women increased by 2.4% (p<0.05) in response to a stressful stimulus. The growing of this biochemical blood parameter by 4.0% (p< 0.05) was also observed in group B women. This fact indicates significant energy expenditure during the creatine phosphokinase mechanism of energy supply. The results of biochemical control recorded after 12 weeks of research showed that the creatinine concentration did not change in response to a physical stimulus in representatives of both groups. The basal level of creatinine in blood serum of group A women increased by 2.3% (p<0.05). These changes specify a positive trend towards the growth of muscle mass, which is extremely necessary after prolonged hypokinesia.

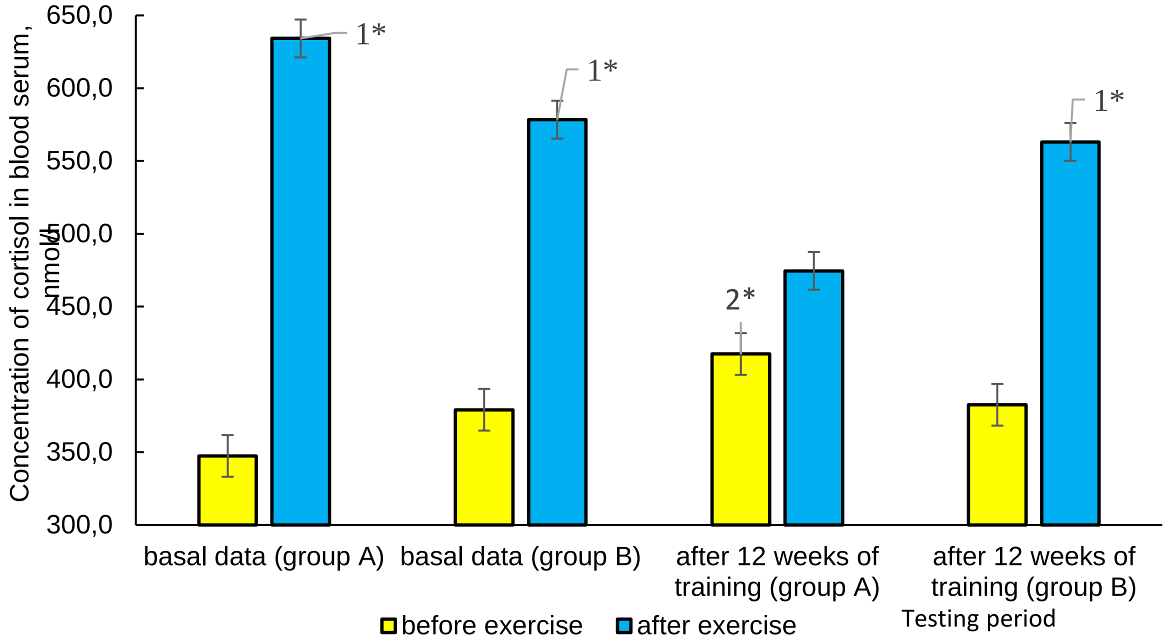

Fig. 2. Changes in cortisol concentration in the blood serum of study group participants using free weight exercises (A) and machine exercises (B) during the research, n=52
Note: [1] – compared to the indicators before exercise; [2] – compared to the indicators before the study; * – $p<0.05$

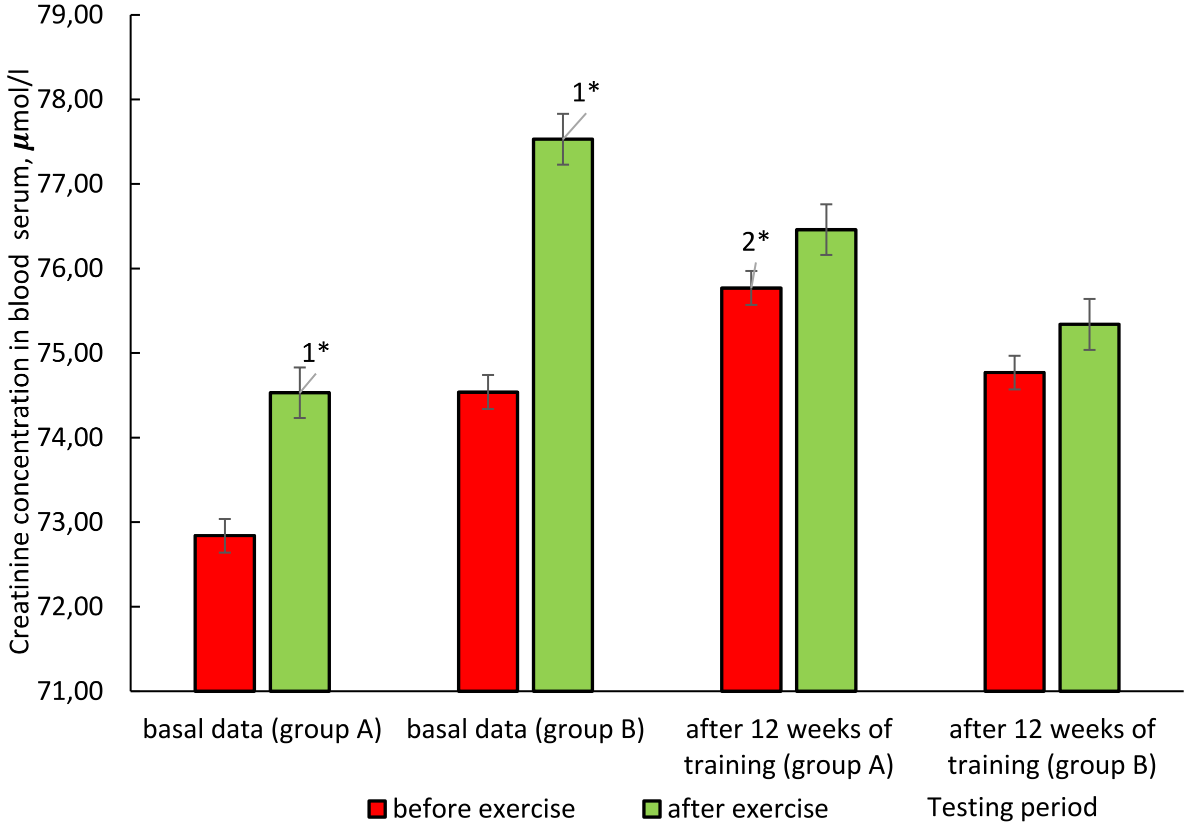

Fig. 3. Change in creatinine concentration in the blood serum of study participants using free weight exercises (group A) and machine exercises (group B) during the research, n=52
Note: [1] – compared to the indicators before exercise; [2] – compared to the indicators before the study; * – $p<0.05$

Discussion

This study is dedicated to researching the influence of various kinesiological models of neuromuscular system readaptation on adaptive body changes in mature women after prolonged hypokinesia. The research is based on a direction in kinesiology, which is aimed at the development of integral models involving modern tendencies in the physiology of motor activity, dynamic anatomy, fitness, biochemistry of motor activity, diagnostics of body systems. The obtained results indicated that using free weight exercises with changes in kinematic characteristics in the kinesiological model contributed to pronounced adaptation processes after prolonged hypokinesia. The research results will contribute to the improvement of kinesiological models of the neuromuscular system readaptation. They will help to understand ways of optimizing physical activity depending on the features of adaptive and compensatory reactions to a stressful stimulus. They will aid with identifying informative physiological and biochemical markers of assessing the processes of the neuromuscular system readaptation to adaptive changes in the body of mature women after prolonged hypokinesia.

BIA results testify to the effectiveness of using free weight exercises in the kinesiological model with a change in the kinematic features of the performance technique. Thus, the use of this model leads to a decrease in the level of body fat on the background of a significant increase in fat-free mass and body cell mass. These changes in body composition indicators prove the activation of compensatory mechanisms in the body to provide the necessary amount of energy resources in the proposed conditions of muscle activity [2]. The body composition indicators in women using the kinesiological model with machine exercises did not change significantly. It is possible that the obtained results indicate a high level of body resistance to the stressful stimulus or an insufficient level of load intensity [3, 10].

The body circumferential measurements decreased in all participants, but in group A the rate of change was by 1.8 times faster. The nature of these changes indicates that using free weight exercises requires the involvement of additional muscle groups to stabilize the position of the body in space. In this case the activity of intermuscular coordination increases, which requires significant additional energy supply [11, 18].

The study revealed that the strength endurance growth in women of group A and the maximum muscle strength development in women of group B went on with almost the same progression. Taking into account the initial parameters of the adaptive body reserves of the examined women after a long period of hypokinesia, it is possible to make assumptions about the increase of intra-muscular coordination [2, 10]. This process occurs due to an increase in the number of active mobile muscle units [11]. However, increasing the level of intra-muscular and inter-muscular coordination leads to a significant increase in energy consumption and the need to increase the functional capabilities of the body [16, 19].

The results of changes in the cortisol concentration in the blood serum of women of mature age after prolonged hypokinesia confirmed the data of studies where a contingent similar in age and gender participated in conditions of power fitness [10]. An increase in this hormone concentration in the blood at the beginning of the study indicates a low level of body adaptation to stressful stimuli. The absence of significant changes in the cortisol concentration in the blood serum in response to proposed loads testifies an increase in the body resistance level [1, 15, 19]. The growth of the creatinine basal level after using the kinesiological model with free weight exercises shows expanding of adaptive body reserves. Adaptation processes are associated with the improvement of the creatine phosphokinase mechanism of ATP resynthesis and the growth of muscle mass [2, 14].

Thus, after a series of studies it can be stated that an integrated approach to the development of a kinesiological model allows to clearly determine the course of adaptive-compensatory reactions in different conditions of muscle activity. Using free weight exercises with a change in kinematic characteristics is the most optimal physical stimulus for increasing the functional capabilities of mature women after prolonged hypokinesia. In such conditions of muscle activity, an increase in strength endurance and indicators of FFM, BCM in study participants with a significant decrease in the level of their body fat mass was observed.

Conclusions

Using free weight exercises in the kinesiological model with a change in kinematic characteristics contributed to the positive dynamics of the morphometric body indicators of mature women after prolonged hypokinesia. Additional involvement of the muscles stabilizing the body in space enabled increasing the level of intermuscular coordination and the level of the body resistance to similar energy-intensive loads due to expanding creatinine reserves. Growing reserves of the creatine phosphokinase mechanism of ATP resynthesis increase the body functional capabilities, which is extremely important in the state of hypokinesia. The obtained results contribute to the determination of informative markers for the assessment of the process of the neuromuscular system readaptation and will allow in the future to develop mechanisms for correcting the structure, load indicators and direction of a kinesiological model. Practical implementation of research results will help to improve kinesiological models taking into account the individual condition of a person, their needs and prospects.

Conflict of Interest

The authors hereby declare that they don't have any financial and personal conflict of interest.

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