

REVIEWS

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Exploiting system fluctuations. Differential training in physical prevention and rehabilitation programs for health and exercise

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Summary. *Background.* Traditional causal modeling of health interventions tends to be linear in nature and lacks multidisciplinary. Consequently, strategies for exercise prescription in health maintenance are typically group based and focused on the role of a common optimal health status template toward which all individuals should aspire.

Materials and methods. In this paper, we discuss inherent weaknesses of traditional methods and introduce an approach exercise training based on neurobiological system variability. The significance of neurobiological system variability in differential learning and training was highlighted.

Results. Our theoretical analysis revealed differential training as a method by which neurobiological system variability could be harnessed to facilitate health benefits of exercise training. It was observed that this approach emphasizes the importance of using individualized programs in rehabilitation and exercise, rather than group-based strategies to exercise prescription.

Conclusion. Research is needed on potential benefits of differential training as an approach to physical rehabilitation and exercise prescription that could counteract psychological and physical effects of disease and illness in subelite populations. For example, enhancing the complexity and variability of movement patterns in exercise prescription programs might alleviate effects of depression in nonathletic populations and physical effects of repetitive strain injuries experienced by athletes in elite and developing sport programs.

Introduction

Returning to a healthy state after injury or disease or prevention of ill health and disability (in order regain or maintain lifestyle quality) seems be a major goal across the globe, especially for white and blue collar workers, athletes and for individuals who work at home fit with the job demands in the current tense economic context. Despite the development of increasingly sophisticated technology for occupational health and safety diagnostics, the scientific basis for subsequent physical rehabilitation therapy programs appears to be not well understood. A major problem of the challenge in transferring emphasis in health initiatives away from diagnostics toward the development of preventive interventions seems to be created by adherence to the classical scientific experimental methodology implemented in clinical rehabilitation programs, where usually one variable is modified while all others are kept constant (1).

For the treatment of movement disorders that are caused by spontaneous injuries or chronic postural problems, typically two approaches (models) are ap-

plied: clinical testing and biomechanical movement analysis. Both approaches are based on models of behavioral changes that have in common the subsequent interpretation of a single individual's test score or biomechanical data based on averaged larger groups that are clinically defined as "apparently healthy" or "normal." By relying on these normative, group-based methodologies, clinical measures, which deviate from a perceived normal value, are averaged toward the clinical "normal" zone. Based on these methods, a strong causality for variations in health parameters is not constructed considering specific tolerance thresholds. In contrast, a weak causality of health variables assumes identical effects based on identical causes (2). These implicit assumptions are in accordance with the classical scientific approach where a system is analyzed by means of experiments, which only allow variation of single variables while keeping the values of other intervening variables constant. If the influence of several interrelated variables is assumed, then typically the values of these variables are modified suc-

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cessively by keeping all other variables fixed again. Complex interactions of several variables, unfortunately, are rarely investigated and simulated in clinical biomechanics models of movement disorders based on differential equations. The underlying model of cause and effect for such approaches is a nonlinear model. As a consequence of the classical linear models of cause and effect, strategies for exercise prescription and interventions have been adapted from sports training programs leading to a great deal of similarity of interventions in exercise rehabilitation programs and sports training. Mainly, four classical approaches in motor learning have been pursued in sports training interventions: a) the repetitive approach (3); b) teaching on the basis of methodical rows of exercises (4); c) variability of practice training in accordance with Schmidt (5); and d) the contextual interference approach adopted from language acquisition (6) to motor control (7). Major problems of these approaches are common implicit assumptions of an ideal movement template (model) that is constant over time, fairly narrow, and independent of the individual learner/performer. A major distinction within these classical approaches is the method of progressing toward this ideal template (model) or target from different initial states.

The main aim of this article is to discuss the implicit assumptions of these classical motor learning theories for exercise rehabilitation interventions and to suggest alternative consequences from other assumptions that are already well established in the literature, but in most cases only serve for the explanation of exceptions to assumed “normal” behaviors. These alternative explanations are predicated on the notion that neurobiological system variability is an inherent feature, which can be exploited by individuals to maintain health or enhance learning. In addition, a further related aim is to provide a theoretical basis for several alternative approaches that coincide with the explanation of linear models of diagnosis and interventions but rather have been named master theories. Nevertheless, they have challenged the assumptions of classical models and generate a more general understanding of the design of therapeutic interventions.

Classical motor learning approaches and their implicit assumptions

The most common and oldest theoretical approach to learn specific movements is the repetitive approach (3) in which a target movement is repeated frequently for the purposes of imitation. This approach proposes that learners improve a skill just by repeating it. In psychological learning theories, this approach is most similar to learning by imitation in connection with reinforcement learning (8). In practice, the imitations by individuals tend to display

decreasing deviations from a to-be-learned movement that can be described by an exponential function (9). Here we should note that the improvement of a movement implies a deviation from a previous movement execution and, although the learning effect is assigned to the repetition of the execution, it can be questioned whether the learning effect was due to the deviation as well. From this theoretical perspective, therapeutic rehabilitation programs are based on the production of numerous repetitions of a perceived “optimal” exercise pattern by a patient, accompanied by corrective instructions and feedback from therapists.

Almost the same degree of recognition has been given to the approach of methodical rows of exercises (4). In this training or teaching strategy, in addition to the presence of a target movement template, the initial athlete's conditions are taken into account in order to successively approach the target movement by means of increasingly similar exercises. The type of exercises used in interventions is mainly chosen based on principles of kinematic and dynamic congruence of training and target exercises (10). According to these pedagogical teaching principles, exercises are selected along continua from easy to hard and from simple to complex. Once the exercises have been chosen for an intervention program, every exercise is repeated several times according to the repetitive approach until observed movement deviations drop below a specified tolerance threshold. In this way, the training exercises are considered as preparatory training for production of the specified target movement. Once the target movement can be imitated within certain variation limits, the target movement is typically trained with numerous repetitions. The methodical rows of exercise approach can be considered as an extension of the initial preparatory phase of the repetitive approach where bigger deviations in the beginning can be observed. It is important to note that both approaches end up with an ideal target movement template that has to be repeated until the levels of perceived deviations are reduced over time. Typically, this approach is supported by means of frequent corrective instructions and feedback from the therapist or trainer.

Distinct from the previous two approaches, which display a rather normative background with a close connection to historically dominant ideas in teaching philosophy, the variability of practice approach suggested by Schmidt (5, 11) is derived from a more psychologically oriented concept of motor control. The model distinguishes among invariant and variable components of movements, whereby the invariant parts are inherent to a range of similar movements that are grouped together in specific movement classes by means of a generalized motor

program (GMP). For a specific movement execution, the GMP is connected with discrete variable parameters by means of schemata. Despite the fact that the schema theory developed by Schmidt (5) was originally intended to model only highly automated ballistic movements, specific consequences for the acquisition of motor skills were derived. A major consequence is the claim that a GMP, mainly measured in relative force and relative timing variables, achieves increasing stability when it is trained with a high number of variable parameters (11, 12). Originally, the training recommendations were directed toward a blocked training sequence signifying that an invariant is repeated several times with a specific variable parameter before the next specific variable parameter is connected with the GMP. In comparison to the previous approaches, the variability of practice approach widens the inclusion of variability into the acquisition or learning process in so far as the stability of a generalized motor program is brought into direct connection with the movement variability present during a skill acquisition program. Despite the provision of supportive data with respect to the existence of some movement invariants (13) and the variability of practice hypothesis in laboratory tasks (14), in health care (15) and multisegment motor tasks (16), a detailed methodological analysis of the empirical basis of schema theory (17) led to the ramification that, “the variability prediction cannot, therefore, rest upon consistent supportive evidence, neither with adult nor with child subjects” (17). Beside the methodological shortcomings of the analyzed designs in order to test the variability of practice hypothesis with respect to learning effects, the biomechanical basis for detailed movement analysis has been widely neglected. In short, the invariants described by the schema theory are exclusively based on muscular forces by neglecting gravitational and inertial forces as they typically occur in every days or sports movement. Furthermore, a discussion of the findings on the background of an alternative, mainly biomechanically and neurophysiologically based motor control approach like the equilibrium-point hypothesis (18–20) where movement mainly is controlled by the relative length and relative tension of two antagonistic muscles never took place. However, despite the lack of research evidence, the generalized motor program is assumed as an invariant that has to be repeated as often as possible in connection with the variable parameters and therefore relies on blocked repetitive training as well.

The influence of the time sequence of exercises on the learning, of a single and a set, of movement patterns (as evaluated in a retention test) shifted the focus of research to the contextual interference (CI) approach (7). CI research has provided evidence that practicing several skills in an interleaved or

random fashion produces some short-term interference (degradation of performance) occur but results in better long-term retention compared to blocked practice. Reviews of the contextual interference literature regarding the influence of practice schedules in retention and transfer have reported mixed results (21–23). Positive effects of random practice schedules in a number of sport skills have been observed (e. g., badminton (24); baseball (25); kayaking (26); volleyball (27)). From a psychological point of view, two hypotheses for the explanation of the phenomena are discussed. The elaborative-processing hypothesis is related to the elaboration of the memory representation of the skill variations that a learner is practicing (7). The forgetting-reconstruction hypothesis argues that by switching between at least two movements, the learner is forced to “dump” a given pattern from working memory in order to learn to plan and execute the to-be-learned movements (28, 29). Because a given pattern is superseded by planning and execution of trials of another program, it must be drawn from long-term memory or constructed from scratch (30). Recent transcranial magnetic stimulation (TMS) experiments provide support for the elaboration hypotheses by showing that perturbing information processing, evoked by random practice, deteriorates the original benefit of random practice. On the other side, unlike the prediction of the forgetting-reconstruction hypothesis, TMS perturbations during blocked practice did not significantly improve motor learning (31).

A transfer of these ideas to non-sport-related tasks like automatic bank machine learning (32) and physical rehabilitation following stroke (33) supported the theoretically predicted advantages of random practice. Discussions of contextual interference effects have been engaged in areas as speech rehabilitation (34, 35), as well as in physical therapy (36) and occupational therapy (37). Nevertheless, a transfer from motor learning theories to physical therapy training especially for rehabilitation of low back pain is considered critical because of too many discrepancies between exercise and motor skill learning (38).

However, although the CI approach in comparison to other three approaches suggests the greatest amount of variation, it still relies on the assumption of a narrow fixed target movement template that has to be programmed by an adequate number of repetitions. Thereby, the assumed program seems to become more stable when the to-be-learned movement can be compared with a second to-be-learned movement already during the acquisition process. A problem with the transfer of this idea to physical therapy rehabilitation programs is the selection of the optimal additional type of movements because typically a single movement like walking after hip

or knee replacement is required in a rehabilitation program.

Two implicit assumptions revised

The two major assumptions, which the classical motor learning theories rely on, can be considered as follows: a) the to-be-learned movement is considered to be independent of an individual and independent of time; and b) the performance with respect to a to-be-learned movement can be improved by repetitions of at least invariant parts of the movement. In both cases, mostly detailed biomechanical diagnosis is undertaken for the purposes of constructing an ideal movement technique. Most intriguingly, both assumptions are accompanied by two observations that directly limit their influence: the phenomenon of individuality and the low probability of the production of identical movement repetitions. Unfortunately, both phenomena are most often interpreted as the exceptions to a specified rule, rather than studied as phenomena in their own right. Individuality is used for explanation as a form of exception, when the data do not fit into the scientific group-oriented approach, and the low probability of identical movement repetitions is interpreted as measurement error or as destructive negligible motor system noise.

Evidence against the production of identical movement patterns

With respect to the low probability of the production of an identical movement pattern, a rather long history exists in the literature. Heraklit once provided the philosophical adage that “You will never step into the same river twice” and Bernstein transferred it to the study of human movements with his famous definition of practice as “repeating without repetition.” In biomechanics, Hatze (39) has extensively discussed chemical, biological, and biomechanical aspects of the extremely low probability of identical movement repetitions. Sensory noise and feedback delay are also considered as potential sources of instability and variability for the online control of movement (40). Biomechanical analysis of athletic movement production with several thousand repetitions, such as high-performance athletes in Karate (41), national team discus (42), or javelin throwers (43), or even the kinematic analysis of reaching movements in normal healthy individuals (44, 45) revealed even after thousands of repetitions that there was still significant levels of variability in movement outcomes. Overall, this observation leads to questioning of the assumption of how movement repetitions can be achieved. If movement repetitions are never identical and even after several thousand repetitions we can diagnose deviations, then it is really plausible to consider an approach that prepares

the individual for the novel aspects of a movement repetition and that will occur anyway. Furthermore, the time independence of the chosen ideal movement template is not valid as well.

In addition to the problem of time independence, recent research supports the problem of person independence in motor learning as well. Although medical treatment and physical rehabilitation therapy as well as high-performance sports are normally targeted toward and realized for the individual patient and athlete, most research efforts are put into group-oriented research with very small effects on the specificity of the individuals. In sports training the father of training principles (46) dedicated the first training principle to this phenomenon. Despite this dedication, exercise training science primarily is oriented toward analysis and development of group performance outcomes and averages. Predicated on evidence that identification of individuals by means of different biometric data such as face recognition (47), fingerprint (48) or ear recognition (49), there is a clear possibility of recognizing individuals on the basis of kinematic or dynamic movement data as well. By analyzing the kinematic and biomechanical data of the lower extremities of 14 female participants only during a single ground contact in gait, Schöllhorn et al. (50) were able to recognize each individual subject by 96%. Most intriguingly, the recognition was stable when participants walked in different heel heights up to 5.4 cm. Once the participants switched to 8.1 cm in heel height, the recognition rate increased to 100%, a finding that was interpreted as displaying the real individual characteristics even better in extreme performance situations. Furthermore, by switching to a different heel height, individual patterns of adaptation could be identified as well. Based on perceiving only silhouettes of individuals, Nixon et al. (51) were able to identify single participants with an 85% rate. Whether specific insole treatment of Parkinson patients was effective, it could be diagnosed for each individual subject by means of foot pressure data as well. Once the data of the pretest could be clearly (disjunctively) separated from the data of the post-test, the intervention was diagnosed as successful (52). The analysis of demonstrated emotions and emotions elucidated by music during gait on 22 and 16 participants was the objective of Janssen et al. (53). Again, the individuality dominated the recognition process with respect to dynamic, kinematic, or both data sets. Once the individuals were identified, the recognition of the demonstrated and music-induced emotions was possible for up to 100%, in average 84% over all participants and trials. In another study, the participants fatigued themselves by means of exhaustive leg extension exercises. The ground reaction force patterns during a single gait

ground contact immediately before and after the intervention were dominated by the recognition of the individuals first and afterwards the influence of fatigue differentiated the individual gait patterns in more detail (54, 55). Despite all the diagnosed individual dominance and all the automaticity of the gait movement, no identical gait pattern provided further evidence for the presence of continuous fluctuations in our movements.

System fluctuations: a necessary phenomenon for adaptation

Despite the recognition of variability in all kind of movement repetitions, the inherent noise in movement control was considered a destructive influence until the last few decades of the last century (56, 57). Almost in parallel researchers from different fields of research such as system dynamics, neurophysiology, or robotic research became aware of the constructive influence of noise or fluctuations on system performance with increasing interest. In the field of motor control, the outstanding works of Haken et al., Schöner et al., and Kelso (58–60) suggested a revised view of system fluctuations as functional and made several predictions that were validated subsequently. By means of simple rhythmic finger, arm, and leg movements, the fundamental influence of fluctuations, especially during the transition between two stable system states could be shown. However, although fluctuations were diagnosed as fundamental in human movements, learning was still recommended in the form of movement repetitions (61). The constructive influence of noise was also shown in the physiology of heart rhythms (62). In robotic research, the addition of noise during the training process of robots revealed better results in the subsequent practical or application phase than training without noise (63). The most familiar applications of constructive noise (although termed differently) in the area of physical training concern the suggestion of using variable exercises for increasing postural stability (64) or perturbations training for regeneration or for preventing falls (65). Immediate effects on postural stability by applying subthreshold signals with a stochastic resonance characteristic to sensors on the soles of the feet were demonstrated by Collins and coworkers (66, 67). Detailed biomechanical analysis of high-performance discus throwers provided further evidence for rethinking the influence of variations (68) on complex whole body movements. Time discrete and time continuous parameter of selected joint angles and angular velocities were observed during training and competition over a period of one year and showed constant fluctuations with changing variation in different variables.

Indirect support for the advantageous influence of system variability was derived from research in the behavioral neurosciences. When a kitten's visual system immediately after birth received only vertical-oriented stimuli during the first sensitive weeks of the development of their visual cortex, they were observed to stumble down surfaces and were not able to recognize horizontal lines (69). The cat's visual cortex was never able to develop neurons that are orientation sensitive. Such a normal development of the visual cortex is only possible, when the visual cortex is stimulated during a critical sensitive period in early development with a big variety of orientation sensitive signals. Because the whole cortex cerebri is structured similarly, i.e. with 6 layers of neurons that are connected to each other in varying distances and in a neighborhood preserving structure (70–72), we can assume similar stimulus sensitivity in the somatosensory and motor areas of the cortex. Later et al. (73) found again in the visual cortex a high sensitivity of adaptation to the similarity of the stimulus: "If successive fixations expose neurons' receptive fields to images with similar but not identical structure, adaptation will remove correlations and improve discriminability" (73). Learning in general seems to be improved with the amount of dopamine that is produced in the striatum during the acquisition process. Dopamine is considered to work as a reward system, and its concentration increases with events that surprise with respect to expectations (74). Consequently, training programs that create most surprising events will most probably support learning the most and will lead to most discriminable cortex areas with greater levels of excitation.

In summary, overwhelming evidence for the individuality of movements as well as for the low probability of two identical movement repetitions in connection with neurophysiological principles and dynamic systems characteristics for adaptive system training or therapy that is based on numerous repetitions is to be questioned.

Differential training – never train in the “right way” in order to become the best

The differential training (DL) approach (68, 75) has been developed according to the principles of individuality, movement system variability and the nonrepeatability of movements based on findings in neurophysiology and system dynamics. Instead of just describing the fluctuations in the DL, they are considered as intrinsic to the movement system and indispensable for adaptation. Fluctuations are understood as evidence for unstable regions of the system, and instead of trying to eliminate them, it is more functional to enhance them in order to discover the space of possible performance solutions

to prepare the athlete or patient for future events. Several predictions were validated in a couple of experiments in sports with subjects of different ages and different levels of performance. At a phenomenological level, one prediction was the facilitation of individuality and the other was ability to adapt in each situation more individually, more rapidly, and more precisely (75). Three soccer experiments with juvenile and adult skilled players within a pre- and posttest design and 8 interventions over 4 weeks resulted in significant higher acquisition rates than classical training methods (76). During the intervention period, perturbations were added to the main technique by means of instruction. Instead of keeping the standing leg stiff, for example, the task was adapted for participants to kick with an extremely bent standing leg. The intervention period was characterized by no precise repetitions and no corrective instructions, but rather one new set of instructions after another. From a classical point of view, the movement executions looked like the training of erroneous movements. In a similar design with two additional retention tests after two and four weeks, students were taught the action of shot putting (77, 78). The results not only revealed significantly higher skill acquisition rates but also a further gain in performance during the following 4 weeks, while the classically trained group was able to improve its performance during the acquisition phase, but relaxed to the starting performance level within the first two subsequent weeks. Furthermore, the individual results displayed some improvements and some decrements in the classical group, whereas in the DL group, only one athlete showed no change at all, while all others improved their performance at least to the same level as the best learners in the classical method group. In addition, the average of three shots in the test situations resulted in the DL group displaying an enormous reduction in variance, while the classical group increased its performance variance during the acquisition phase and dropped back to the initial level at the end of the retention tests. Obviously, the DL approach initiated the development of the most effective individual shot put performance solutions that could be applied in each situation in the most adequate way. In the search for further improvement of the effects during the retention phase, mental training was added in another experiment. After having three weeks of differential training of the service in tennis, the group was divided into three experimental groups (79, 80). One group did nothing for 3 more weeks according to previous DL experiments, the second group had to read training and biomechanical literature about the service technique in tennis, and the third group practiced mental training 3 times a week for

1 hour in accordance with the programs (81). The results showed an expected increase in precision for the classical DL group (as expected). The literature group had a lightly smaller increase in performance, whereas the mental training group had a significant decrease in performance. At first glance, these results seem to be perplexing. However, a second more detailed review of the data reveal an interpretation that provides a rethinking of the assumption of a constant time independent system. By means of mental training based on recorded videos during the acquisition phase, we can see an attempt to keep the mind constant. Meanwhile the body conditions seem to change and are no longer compatible with a time-independent mind, which relies on a body that has changed from 4 weeks ago. On the other hand, when athletes are trained by repetitive movement then mental training can be assumed to increase the variation and consequently increases future performance. In contrast, mental training as a supplement to differential training is a clear reduction in variation and therefore detrimental for performance. If we change the classical assumption of a constant body and variable mind into a continuously changing body and mind (in the most simple case we assume this change as linear), then the system has to increase the noise from the beginning in order to keep up with the physical and mental changes (cf. Fig.). A transfer of the DL approach to the area of writing skill acquisition in school's first grades has revealed similar advantages for the DL group with respect to the pressure on the pencil and with respect to the writing fluency (82).

Transfer to physical training/therapy

The clear advantages with respect to skill acquisition in addition to the overwhelming results in the learning phase independent of gender, age, or

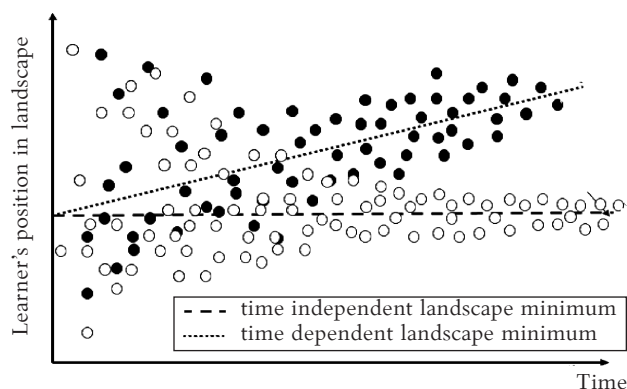


Fig. Two training approaches dependent on the assumption of time-independent (circles) and time-dependent (black circles) target movement

performance level suggest a general learning principle. In accordance with neuroscientific evidence, the self-similarity of the brain, findings in computer science and system dynamics that support the importance of noise in living systems in general makes it plausible to apply the same approach to physical rehabilitation therapies and exercise prescription for counteracting effects of disease and illness. In addition to an immediate application in physical rehabilitation programs, adding noise into the performer's system during performance of a single movement in training before surgery is of some interest. Once the patient is trained differentially in advance, the time span during surgery and postsurgery can be considered as the learning phase like in previous experiments where a further increase in performance could be diagnosed. Furthermore, the theoretical background of DL provides a fruitful basis for the analysis of existing physical training recommendations. Over all the data as well as the perspective of an improved therapy or training process should be worth considering in applications of the DL approach in physical training and therapy. Another application of DL that might have

some clinical benefits concerns the occupational health and safety hazard of repetitive strain injury (RSI) that might exist in work settings where employees repeat a similar movement pattern on many thousands of occasions such as computer operators and process manufacturing workers. Encouraging a rehabilitation program, which includes the introduction of varied movement exercises, may alleviate RSI symptoms by the introduction of variable joint movements and muscle function in a distinct manner. In a similar manner, use of DL methodologies in psychotherapeutic programs to alleviate illnesses such as depression may benefit from varied mental exercises to bring patients out an emotional and psychological environment, which may have become too stable. Finally, in many exercise interventions to alleviate effects of the onset of aging to the musculoskeletal system, using a DL approach is likely to benefit individuals by enhancing the complexity of movement patterns. It has been observed that movement complexity reduces as a result of the aging process (57) and it is possible that a carefully controlled DL intervention may be able to counteract these effects.

Pasinaudojimas sistemos fluktuacijomis: diferencinė treniruotė fizinio pasiruošimo ir reabilitacinėse programose sveikatai gerinti ir fiziniam aktyvumui didinti

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Raktažodžiai: neurobiologinis variabilumas, fizinė reabilitacija, taikomas fizinis aktyvumas, sveikata, diferencinė treniruotė, sistemos fluktuacijos.

Santrauka. Priimta, jog tradicinis priešasčių modeliavimas, įtakojant asmens sveikatą, yra tiesinis ir stokoja daugiapusiškumo, todėl strategijos, sudarant pratimus sveikatai palaikyti, yra sugrupuojamos į optimalius sveikatos būklės siekius, kuriuos turi priimti visi įtakojami asmenys.

Tirtųjų kontingentas ir tyrimo metodai. Šiame straipsnyje mes diskutuojame apie naudojamų tradicinių metodų vidinius trūkumus ir pateikiame neurobiologinių sistemų variabilumu pagrįstas fizinio aktyvumo treniruotes. Neurobiologinių sistemų variabilumo reikšmė įrodyta naudojant diferencinį mokymą bei treniruotes.

Rezultatai. Mūsų diferencinio mokymo teorinė analizė parodė, jog neurobiologinės sistemos variabilumas gali padidinti fizinio aktyvumo poveikį sveikatai. Pastebėjome, jog šis metodas išryškina individualių programų svarbą reabilitacijoje bei fizinio aktyvumo metu daug aiškiau nei grupiniai fizinio aktyvumo metodai.

Išvados. Tolesni tyrinėjimai reikalingi norint atskleisti galimą diferencinio mokymo naudą, taikant ją fizinei reabilitacijai bei fiziniam aktyvumui, o tai gali tarnauti gydant funkcinis bei fizinius sutrikimus poveikio grupėse. Pavyzdžiui, padidėjęs kompleksiskumas ir variabilumas fizinio aktyvumo programų metu gali sumažinti depresijų pasireiškimą nesportuojančiųjų grupėse bei fizinį poveikį besikartojant įtampas pažeidimams aukšto lygio sportininkams pasiruošimo programose.

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