Research Article

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Therapeutic resistance training: proposal for an algorithm-based approach

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Abstract

Background: Ageing, immobilization, sepsis or cachexia reduce muscle mass and function. The age-related loss, i.e. sarcopenia, contributes to frailty and results in a loss of mobility and autonomy in aging and disease. Affected individuals are often socially isolated, have a greater risk of metabolic disorders and psychosomatic problems. As a result, quality of life and life expectancy are affected. Immobilization and lack of adequate stimuli to the skeletal muscle seem to play a central part in these problems. To overcome them, resistance training (i.e., weightlifting) is an effective intervention.

Statement of the problem: Despite the efficacy of resistance training for increasing muscle mass and function, this treatment is underused in clinical practice. We argue that this is due to a lack of a generally applicable methodology.

Methods and framework: To address this and related problems, we have formed the Network of Expertise for Immobilization-induced Muscle Disorders (KNIMS) to develop a potential algorithm for treating sarcopenia and other immobilization-related muscle disorders. An important aspect of the proposed method is that it is defined as a formal algorithm that consists of two stages. Stage A aims to recover bed-ridden patients' ability to stand by applying vibration-tilt table technology. Stage B aims at rehabilitating compromised gait, using a combination of squats, lunges and single leg raises. It is anticipated that this algorithm-based approach will enhance the ability for standardization and documentation, whilst reducing resource efforts at the same

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time, which will be equally useful to clinical practice and to clinical research.

Keywords: muscle training; sarcopenia; falls; mobility; immobilization; physiotherapy; muscle

Introduction

We can interact with our environment only through the strength of our skeletal muscles. This becomes strikingly apparent in diseases with direct or indirect affection of our musculature. It also turns out, conversely, that the prognosis of many diseases depends decisively on the condition of the musculature [1]. In particular, muscular deficits engender restriction of activities of daily living, loss of quality of life and social inclusion, frailty, and the loss of autonomy at the end of the active life span [2, 3]. Within this context, slow and compromised gait can be regarded as a hallmark of disease, aging and death [4]. Interventions to stimulate muscle growth and strength therefore seem a straightforward option in aging and disease.

With that in mind, the present article highlights the physiology of muscular adaption to immobilization and training in order to outline key points for therapeutic resistance training (TRT). Next, we identify common barriers against provision of and participation in resistance training interventions. Based upon that, a novel methodology is devised, namely an algorithm that can guide resistance training for the treatment of sarcopenia and immobilization-related muscle disorders (Figure 1).

Immobilization effects on the musculature

The striated skeletal musculature accounts for about 20–50 % (average 30–40 %) of the body mass [5]. As a tissue, muscle can adapt its size, metabolism and functional properties to different forms of exercise and other stimuli such as hypoxia or nutrient availability. Muscle plays a central role in the aging process, where 'sarcopenia' (=age related muscle wasting) leads to dwindling mechanical power [6]. That process seems to be inevitable, as even highly active people lose around 5 % of their muscle mass per decade of age. Although the exact mechanisms of sarcopenia are not yet understood, anabolic resistance, i.e. the inability to foster muscle protein synthesis in response to anabolic stimuli (e.g. amino acids [7], resistance exercise [8], or hormones) seems to be crucially involved [8]. Of note, anabolic resistance is also induced by physical inactivity [9] and in critically ill patients [10]. Taken together, the question therefore arises in how far muscle wasting in aging and disease are explicable by immobilization.

There is a wide spectrum of immobilization in modern populations that comprises, amongst others, neurological deficits (e.g. spinal cord lesions), systemic diseases (e.g. heart failure), trauma and surgery (clinical bed rest), and quite frequently also a 'sedentary' lifestyle (e.g. motorized transportation). All of these types of immobilization lead, to a different degree, to a significant decrease in muscle mass and strength. The immobilization effect is mostly driven by a reduction in muscle protein synthesis, with no or only little changes protein break down [11]. Under such conditions aerobic metabolism is reduced and a temporary denervation and re-innervation of muscle fibres occurs [12]. After only three days, type I fibres atrophy, the proportion of hybrid type I/II fibres increases, and muscle fibres that express neural cellular adhesion molecules as a sign of denervation can be detected histologically [13]. In addition, muscular protein and carbohydrate metabolism are compromised, leading to peripheral insulin resistance [14]. At the cellular level, sodium conductance and current density increase, causing more rapid muscular fatigue [15].

Bed rest-induced muscle atrophy is most pronounced in the leg, where it mainly affects the plantar flexor muscles, and to a somewhat lesser extent knee extensor, hip and back extension muscles [16]. However, the atrophy rate is also varying within muscle groups, and addition of hypoxia to the bed rest leads to aggravation of thigh muscle atrophy [17]. In addition to immobilization effects, systemic inflammation that is present in rheumatoid arthritis, COPD, liver cirrhosis, depression and many other diseases, can be an independent driver of muscle wasting. Whilst immobilization is acting mainly through hampered protein synthesis, inflammation also fosters muscle protein breakdown, thereby aggravating and accelerating muscle wasting [18]. Taking this altogether, the picture of a vicious circle is emerging, in which the catastrophic reverberations between immobilization and muscle wasting lead to complex biopsychosocial interactions and thereby to frailty and the restriction of radius of action and autonomy (Figure 2).

Resistive exercise as central therapy against muscle wasting

Numerous studies demonstrate that resistance training is effective for increasing muscle mass, strength and power in

Figure 1: Graphical representation of the study. Keys points: (1) the project attempts to overcome barriers in the treatment of immobilization-related muscle disorders. These disorders are highly prevalent and are causing widespread damage; (2) via expert panels, feasibility and acceptability as key issues that withstand administration of therapeutic resistance training. Main issues are lack of space, of apparatus, and of a common treatment standard; (3) the main outcome is the proposition for a training algorithm that standardizes a client-centered training approach with minimal requirements to space and apparatus. This algorithm is deliberately robust and simple, so that it can be administered by wide spectrum of medical and nursing professionals. Figure created with BioRender.

patients and healthy individuals. The biological responses to resistance training involve strain sensing molecules (e.g. focal adhesion kinase [19]), intracellular calcium handling and sensing of energy state (e.g. via adenosine monophosphate), to impinge on the Akt/mTORC1 as master regulator of muscle protein synthesis [20]. A training stimulus leads to a measurable activation of protein synthesis within 60 min of exercise that is maintained for up to 48 h after exercise [21]. In addition, myokines are released that trigger metabolic, cardiovascular and antitumor effects, and epigenetic modifications are elicited that help to stabilize muscle growth [22].

The combination of frequency and intensity determine the effects of the training stimulus: whilst relatively few high-intensity contractions near the 1-repetition maximum can build bigger and stronger muscles, large volumes of

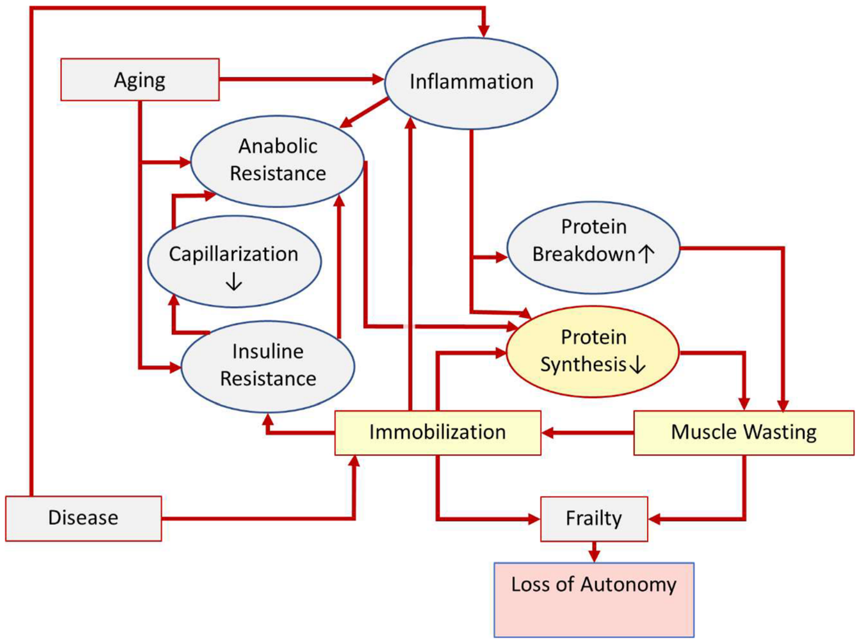

Figure 2: Conceptual framework of the factors involved in immobilization-related muscle wasting. Aging and disease are the initiating steps, and inflammation, anabolic resistance, reduced capillarization and insulin resistance. The balance between protein synthesis and protein breakdown determines whether muscle mass is wasted or gained. The central part in this schematic is played by immobilization, hampered protein synthesis and muscle wasting. The latter has great potential to further aggravate immobilization, thereby initiating a vicious circle. Ultimately, this result in frailty, loss of autonomy and psychosocial deprivation.

lower-intensity contractions drive the muscle towards an endurance phenotype (type-1 fibers). Masters athletes may not depict the reduction of type-2 fibers [23] that is often observed in the general population [24], which nourishes the hope that training at older age may not only reverse muscle wasting, but also the loss of muscle endurance with age. More specifically, high resistance training for hypertrophy typically comprises two to three sessions per week, each with two to three sets of approximately 10 contractions that are subjectively perceived as hard to very hard. Ample evidence demonstrates that high resistance training continues to be effective into older age, including in sarcopenic patients [25]. The benefits of therapeutic resistance training have also been demonstrated for a variety of other conditions, including COPD, rheumatoid arthritis, heart failure, depression, and many others [26].

Experimental bed rest is a ground-model of weightlessness that has been extensively used to develop countermeasures for spaceflight. From the numerous studies over the past three decades, two effective approaches have emerged, namely the so-called reactive jump training (Figure 3A) and resistance vibration training (Figure 3B) [27, 28]. Both types of training have to be performed very vigorously, and at least 5 times per week in order to prevent muscle wasting and bone loss. For two reasons, it is also interesting that both approaches involve a plyometric component (i.e. elongation of the contracting muscle): from a physicist's point of view, jumping exercises involve large mechanical stresses in the musculoskeletal tissues, and from a physiological perspective, the so-called stretch-shortening cycle enhances the muscle's force-generating potential [29].

The specific equipment developed for these studies has meanwhile been adapted for application in pediatric rehabilitation. Here, combination of vibration platform and a tilt-table (Figure 3C) helps patients with weak muscles, disturbed balance or limited compliance to perform exercises that would otherwise not be possible. This concept has proven extremely successful for enabling and improving balance and gait in patients with cerebral palsy [30] and a variety of other pediatric disorders [31]. Because whole body vibration elicits stretch reflexes, it can be considered as partially passive exercise. An alternative approach could consist in neuromuscular electrostimulation, which is increasingly being used for athletics and life-style [32]. However, its application in medical therapy is not always straightforward.

Whichever physical intervention is chosen, it will also be essential to safeguard adequate dietary protein supply, in order to reap the full training benefits [33]. In addition, creatine could also be considered as a dietary supplement to improve training effects [34]. On the other hand, protein supplementation without concomitant resistance training is futile, which means that resistance training should be regarded as central factor. Attempts have also been made to enhance muscle contraction through mental imaginery, with mixed results [35].

In essence, therefore, the only currently practicable approach to counter immobilization-related muscle wasting and sarcopenia is resistive exercise.

A: Deutsches Zentrum für Luft- und Raumfahrt e.V.
B: Musculoskelet Neuronal Interact 10(3): 207-219.
C: MedizinFoto Köln, University Hospital Cologne

Figure 3: (A) Jump sledge system for performance of reactive jumps in horizontal position. Participants are affixed with a harness and with a thigh-belt, which are both guided in a low-friction linear bearing. The push-down force is generated via a pressurized cylinder and transmitted via the harness. Application of the full body weight can cause issues in shoulder and back. (B) Resistance vibration system for bed rest. Whilst generation and transmission of the push-down force is similar to (A), this system affords a vibration platform, and it only allows exercises such as squatting, toe-stands and heel-stands, but no jumping. (C) Combination of tilt table and vibration platform is already routinely used in pediatric rehabilitation. Whilst the system is principally comparable to (B), partial verticalization by the tilted table replaces harness-loading. The whole-body vibration enables a partially passive form of exercise, which on the one hand leads to reflex-mediated contractions, and on the other hand facilitates the control of movement when communication is difficult.

Barriers in clinical practice and how to overcome them

Even though the benefits of TRT are not disputed, there are important barriers usually that currently prevent its application in the clinic. Firstly, there is a lack of awareness. For example, whilst scientific studies predict a sarcopenia prevalence between 10 and 30 % for people over 80 years, the diagnosis of sarcopenia is assigned to less than 1 % of that age group in a typical German health insurance cohort (Rittweger et al. unpublished data). Moreover, there are gaps in knowledge and communication deficits between nurses, physiotherapists, exercise therapists and medical doctors, so that none of these professional groups is typically aware of all facets of the challenge. Secondly, the general view is that resistance training would require bulky and expensive exercisers, and neither those nor the rooms for them are available in hospitals or nursing homes. Fourth, medical staff are already overworked, and it will be generally difficult to find additional staff. Fifth, thresholds for patients are often too high in required commitments for time, exertion and organizational effort. Adapted concepts may be required for other populations, such as e.g. patients living with degenerative neuromuscular diseases, and particularly with a group called myofibrillar myopathies need to be considered.

Clearly, to overcome these important barriers would require a multidisciplinary, generalized and yet simplistic approach, to provide a standardized training plan that is applicable from bed-ridden patients up to recovering full mobility.

Development of a systematic approach for TRT

In search for a possible solution, the Network of Expertise in Immobilization-related Muscle Disorders (www.knims.de) has regularly met and undertaken a structured discussion process. The principle basis of exchange were annual Spring meetings, with numerous additional virtual splinter group meetings. Discussions first focussed on efficacy of TRT, and a splinter group (KP, BM, JR) was formed to assess the published evidence on therapeutic training interventions.

General efficacy of exercise interventions for health

Given the large number of publications on this topic [26], the focus was set on meta-analyses, and an umbrella review of meta-analyses was found that summarizes the findings from 85 meta-analyses that each covered a lumped number of >100 patients [36]. For 22 different chronic diseases, results demonstrate improvements in 126 of 146 functional capacity outcomes. The standardized mean differences ranged between −0.18 (−0.54 to +0.18) for stair climb in cancer patients and +1.52 (1.07 to 1.98) for isometric strength in patients with rheumatoid arthritis. Effect sizes varied much more in relation to outcome and disease than with regards to the exercise protocol (either resistance, aerobic or combined resistance and aerobic exercise). The KNIMS network therefore concluded that the evidence for the efficacy of exercise interventions in those, and possibly other, chronic diseases is overwhelming.

Feasibility, efficacy and acceptance of TRT for treatment of sarcopenia

However, that umbrella review did not cover the topic of sarcopenia, which is another important target of TRT. A systematic literature study was therefore performed (by JB, LS and JR) on the feasibility, efficacy and acceptance of TRT for treatment of sarcopenia (Table 1).

Feasibility: This literature study identified six publications on feasibility of TRT, of which only two contained results, as they were reports from clinical trials (Table 1). In both cases, these results were in the sense that the intended TRT protocol turned out to be feasible. However, no detailed aspects of feasibility were reported, such as implementation cost or barriers against feasibility, which would be standard in the fields of engineering or economics. It was therefore concluded that our current knowledge of factors that modulate feasibility of TRT in sarcopenia is rather limited.

Efficacy: With regards to efficacy of TRT against sarcopenia, of the 62 publications that were initially identified, only those were included that reported original interventional studies in patients with muscle wasting disorders, and with endpoints that are involved in the diagnostic approach of sarcopenia [37]. Twenty-two studies met these criteria, and 21 of these provide favourable evidence for the use TRT against muscle wasting. Of note, the one study that failed to show efficacy was also the only study that investigated TRT efficacy in the setting of rehabilitation [38] and lacked a passive control group. Given the wide range of methods used for outcomes (i.e. muscle mass by various differing methods, muscle strength, muscle power or gait speed by various differing methods), it was deemed difficult to use the available information to compare efficacy across the various different TRT types (e.g. resistance machines, therabands, body mass only), TRT protocols (1–3 times per week), or settings (home-based vs. gym-based). However, it seems reasonable to conclude that TRT in general may be effective against muscle wasting disorders over a wide spectrum of applications.

Acceptance: With regards to acceptance, all of the seven publications that were initially identified were included into further analyses. Of these, four had used adherence or non-adherence as a study outcome, albeit as a secondary one. In 3 of these studies, adherence ranged from 53 % up to 84 %, and one study reports an adherence of >70 % of participants adhering to>60 % of sessions [39], which in theory could stand for any adherence rate between 42 and 100 %. None of the other three studies stated how adherence was rated, i.e. as adherence to the study, adherence to scheduled sessions, or adherence to single exercises. A questionnaire-based study reported that personality traits can explain 38 % of variance in TRT adoption [40]. Another questionnaire-based study revealed that feeling better with exercise was the main driver, and not being motivated was the greatest barrier against TRT acceptance [41]. In addition, one study assessed acceptance via structured interviews [42]. The

Table 1: Overview of the systematic literature study on feasibility, efficacy and acceptance of therapeutic resistance training for treatment of sarcopenia.

Search terms		Records identified and screened	Records assessed	Outcome
Feasibility	(Sarcopenia OR frailty) AND resistance training AND humans AND feasibility studies	n=6	n=2 [49, 50]	Feasible: 2 Not feasible: 0
Efficacy	(Sarcopenia OR frailty) AND resistance training AND humans AND treatment efficacy	n=62	n=22 [38, 49–69]	TRT favourable: 21 TRT not favourable: 1
Acceptance	(Sarcopenia OR frailty) AND resistance training AND humans AND patient acceptance of healthcare	n=7	n=7 [39–42,70–72]	Adherence to intervention: 4 Questionnaire: 2 Structured interview: 1

authors conclude that ‘drivers for physical exercises were existing habits, social contacts, customized support, and experienced physical improvement’ [42]. It was therefore concluded that major barriers against acceptance of TRT are associated with individual factors, and also that future studies need to be clearer about the rating of adherence, including factors that modulate it.

Expert consensus: Based on these recognitions, discussions within KNIMS therefore focused on factors that determine feasibility and acceptance of TRT across different training approaches. From a clinician’s point of view, the two main barriers identified were lack of space and apparatus for machine-based resistance training, and a lack of qualified staff with experience in resistance training. These difficulties can be overcome by using machine-independent prescription of resistance training, and by formulating an algorithmic approach that could be taught to staff from a wide spectrum of qualifications. Algorithms are nowadays the prevailing paradigm in medicine, as they ‘can help us to articulate how we make decisions, to clarify our knowledge and to recognize our ignorance’ [43]. Methodologically, an algorithmic approach is equally beneficial for enabling clinical practice as well as for scientific evaluation of therapeutic interventions. Therefore, key requirements for such an algorithm were defined (Table 2), and a KNIMS-splinter group (authors WB, SG. JR, LS, HW) was given the task to elaborate such an algorithm. This task was accomplished in repeated exchanges through video conferences, via telephone and via email. Discussions were driven by the wish for an algorithm that can be seamlessly applied across the entire range of clinical immobilization, i.e. from unconscious bed-ridden patients up to patients that are mobile, albeit with restrictions. It is obvious that different methods have to be used for bed-ridden and for ambulatory patients. As mentioned before, two different bed-ridden methods have proven successful in experimental bed rest, namely resistive vibration exercise [27] and reactive jump sledge training [28]. Interestingly, both methods contain elements of plyometrics [44]. Given that it is highly unlikely to find bed-ridden patients that can perform reactive jumping, the KNIMS consortium favoured resistive vibration exercise in bed, with the resistive element being effectuated by stepwise verticalization of the bed.

The algorithm was presented and discussed at the 2021 KNIMS meeting, and some moderate adjustments were made, mainly in identifying and preventing possible adverse effects. In the following, we will present the outline of the proposed algorithm, bearing in mind it will probably not be ‘optimal’ and that it can be and should be challenged by alternative algorithms in the future that include different exercises, exercise progressions of control variables.

The KNIMS algorithm

Much of the algorithm’s definition was based on experiences in pediatric rehabilitation in Cologne, where a long track record exists in enabling immobilized patients getting to walk, often for the first time in their lives. The proposed algorithm, developed through this expertise, consists of two stages, namely stage A that applies to people who cannot stand or walk (bed-ridden, wheel chair), and stage B that relates to patients who can stand, but who have compromised gait. Whilst the aim of stage A is rehabilitation up to upright stance, stage B aims to rehabilitate mobility. Further, it is recommended that all patients continue to practice after their full rehabilitation as a preventive measure (Figure 4).

In stage A, exercise is performed in the patient’s bed (Figure 5), increasing the loading of the knee and hip extensor muscles by step-wise verticalization of a tilt table [45]. By means of the additional vibration component, reflexively triggered contraction mechanisms are exploited to generate muscle work independent of central nervous control. This stage concludes with the achievement of the ability to stand. Stage B then aims at walking ability (Figure 6; videos of the exercises are available in the supplementary material). The central guide parameter is the maximum gait speed. Here, we have adopted a diagnostic threshold of 0.8 m/s, which is also used for diagnosis of severe sarcopenia [37]. The three exercises that were identified by expert-guided selection are squats (targeting anti-gravity muscles), lunges (targeting anti-gravity muscles but also adductors, hip rotators and knee flexors) and single leg raises (targeting hip flexors). Exact details are presented in the Figures 5 and 6.

In both stages of the algorithm, the progressive overload principle is followed by increasing the load once exercising is possible for more than 60 s in stage A [46], and for more than eight repetitions in stage B [47]. This allows standardization of the intervention, as well as individualization of the prescription in order to account for aging and health conditions. Moreover, in both stages, the interventions are supplemented by an isometric force component, the so-called auxo component. This methodology involves holding an inelastic object under permanent tension during the movement, which allows the intensity of the exercise to be regulated voluntarily. Together with the control of further exercise parameters, such as the range of motion, the weight load as well as the degree of freedom of the movement coordination, a subjective exertion can be achieved, which generates effective training stimuli. For documentation, we propose Borg’s RPE scale [48], widely used in sports science, on which a value ≥16 should be achieved.

Table 2: Requirements identified by KNIMS for a feasible, effective and acceptable resistance training therapy.

Requirement		Justification	KNIMS algorithm
Feasibility	Clear diagnostic criteria	Any medical intervention requires a diagnosis, not least for the sake of remuneration	The criterion is gait speed <0.8 m/s. This criterion has been adopted from the diagnostic criteria for severe sarcopenia [37]
	Communicability	All professional groups need a common understanding	The algorithm uses plain language. This has been checked with representative nurses, physiotherapists, exercise practitioners, and patients
	Applicability	Therapy must be applicable for people with wide spread pre-conditions	The algorithm has virtually no exclusion criteria and can therefore be used by almost everyone
	Low demands on apparatus	Most hospitals, nursing homes etc. do not afford gyms for large numbers of patients	Stage A requires in-bed vibration platforms, which seems a reasonable effort for bed-ridden patients. Stage B of algorithm works with minimal equipment
	Low demand on staffing	Hospital and nursing home staff have no time for additional activity	Staff only required for education; after familiarization, patients can exercise by themselves
	Standardized communication and documentation	A uniform terminology is required to facilitate collaborative patient management and documentation	All elements of the algorithm can be easily communicated and documented
Efficacy	Specificity	Clear definition of therapeutic target	The algorithm focuses on those muscle groups that are most important for gait
	Sufficient dose	Musculoskeletal tissues need to experience large enough mechanical stresses	The algorithm involves well-established elements of strength training; rating of perceived exertion >16 is recommended
	Sufficient frequency	At least 5 sessions per week are required to offset immobilization-related muscle wasting	The algorithm proposes 5 training sessions per week
	Individualization	Patients need to train according to their individual needs and capabilities	The algorithm adapts to individual needs in a standardized and reproducible way
Acceptance	Reasonable effort	Overly large time and exertion efforts preclude widened participation	A training unit can be performed in 10 min
	Accessibility	Low organizational thresholds	Training is possible in almost any room
	Encouragement and supervision	Encouragement is important in any exercise and training, and supervision is necessary to monitor exercise progression and to identify issues	Encouragement and supervision are regularly provided by staff

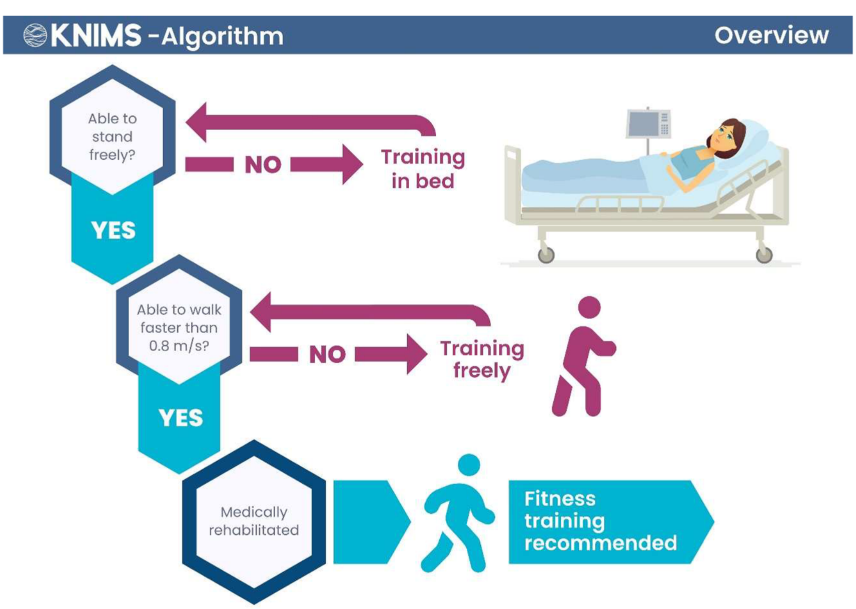

Figure 4: Overview of the algorithm. Initially, a query is made as to whether free standing is possible. If this is answered in the negative, training is performed in bed until the patient is able to stand. Note that this figure is also meant to be used for training staff.

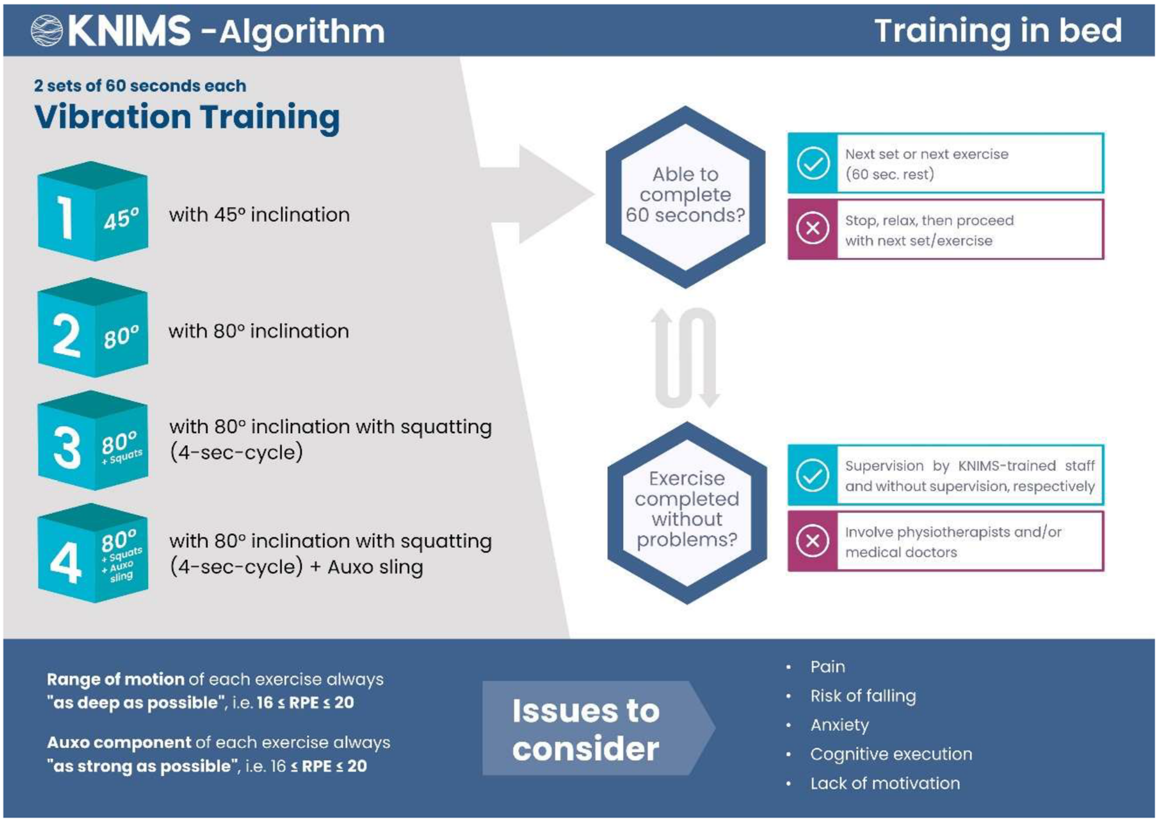

Figure 5: Stage A involves training in bed, which is tailored to patients who are unable to stand.

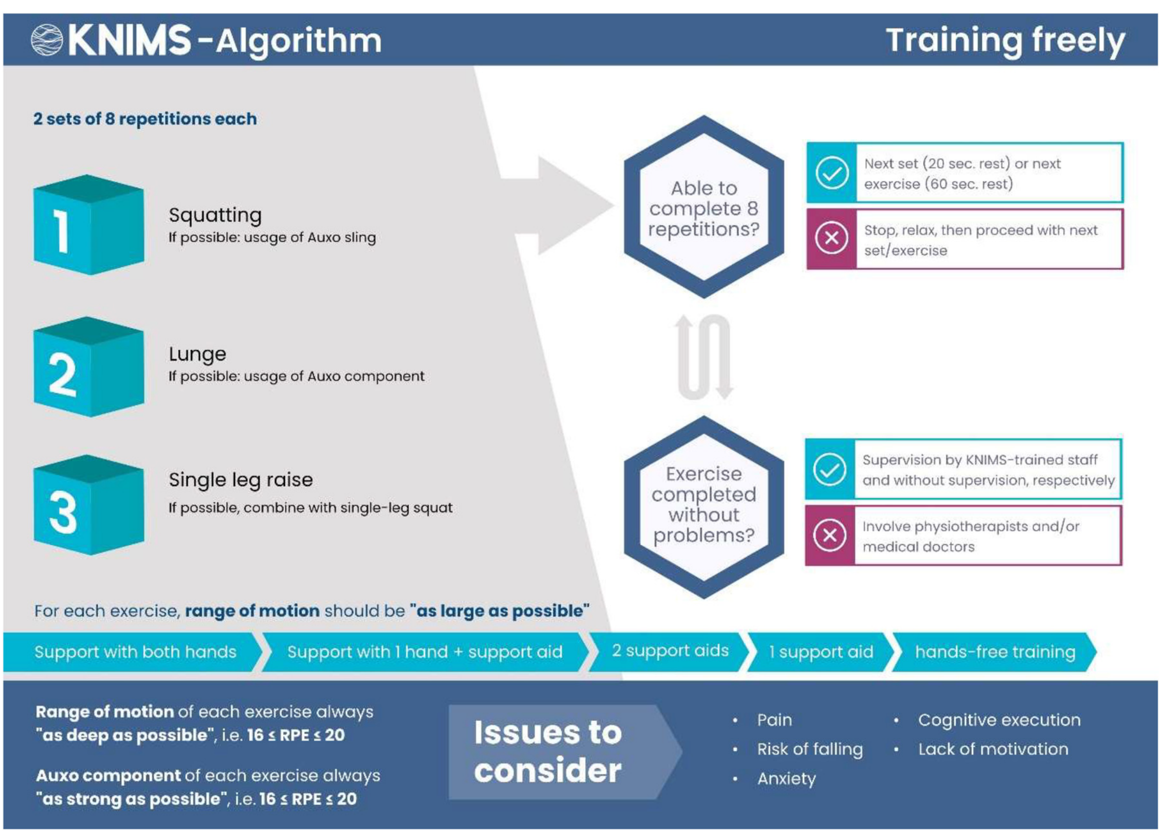

Figure 6: In stage B, free exercises are performed with a load volume of two sets of eight repetitions each. The exercise sequence begins with squats and a query as to whether the load volume is possible without issues with this form of exercise. If this is answered in the affirmative, the transition to lunges and single-leg stands takes place. Stage B is then exited if the walking ability allows a gait speed of at least 0.8 m/s. If this is not the case, the free training is continued. Videos of the exercises are available in the supplementary material.

Limitations and future research

The algorithm is currently based on expert opinion, and it will now be necessary to validate its feasibility, acceptance and efficacy. Unlike previous studies on feasibility, future studies applying the KNIMS algorithm should apply a more balanced framework that assess the various different aspects of feasibility, in order to identify barriers and overcome them. Future studies on acceptance of the KNIMS algorithm should take existing knowledge on board in considering personality traits (as we say in Cologne: jeder Jeck ist anders – each fool is different) [40, 41], and ideally also structured interviews [42]. Adherence needs to be reported in a standardized way so that study outcomes can be better compared. The same applies to outcome measures, where the existing literature on TRT shows a remarkable inconsistency. Clearly, an effort is required to overcome this problem. As a starting point, it would be sensible to use the methods established for diagnosis of sarcopenia [37]. With these methods in hand, it should be possible to validate our proposed algorithmic approach in the near future, and to improve it thereafter. Moreover, future studies may envision differentiation of the algorithm for various types of muscle wasting disorders, such as immobilization, sarcopenia or cachexia, and neuromuscular disoders.

Conclusions

The proposed algorithm focuses on the treatment of the immobilization-related loss of muscle mass, strength, and power. Its methodology is based on efficacy as well as acceptance and feasibility criteria. It is designed for the ample establishment of an everyday 10 min training program that can be integrated as smoothly as possible into the routines of inpatient facilities and is suitable for a broad target group with a heterogeneous physical and cognitive performance level - from persons in need of instruction in long-term nursing care to patients in rehabilitation clinics who can also perform the exercises independently. Although its guiding application is the treatment of sarcopenia, it can readily be applied to many other medical problems. Results from these studies can then be used to improve the approach, either by refining the algorithm, or by demonstrating superiority of alternative approaches.

We would like to refer the reader to the example of the basic life support algorithm, which all health professionals (should) know. Its utility lies in the fact that every health professional can step in when required, with minimal briefing effort. Whilst it was mainly based on expert opinion in the beginning, the improvements that have been effectuated in the past 3 decades were achieved through systematic scientific study. From this perspective, it seems promising, and perhaps even mandatory to fully integrate TRT within the 21st century medicine with an algorithm-based method.

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Competing interests: JR and JB are interested in the clinical utilization of the proposed algorithm. LS is the managing director and owner of two small businesses in the sports and fitness sector, which could potentially benefit from the evaluation and utilization of the proposed training algorithm. All other authors state no competing interest.
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