Optimizing functional exercise capacity in the elderly surgical population

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Purpose of review
There are several studies on the effect of exercise post surgery (rehabilitation), but few studies have looked at augmenting functional capacity prior to surgical admission (prehabilitation). A programme of prehabilitation is proposed in order to enhance functional exercise capacity in elderly patients with the intent to minimize the postoperative morbidity and accelerate postsurgical recovery.

Recent findings
Few studies have looked at exercise prehabilitation to improve functional capacity prior to surgical admission. Prehabilitation prior to orthopaedic surgery does not seem to improve quality of life or recovery. However, prehabilitation prior to abdominal or cardiac surgery, based on 275 elderly patients, results in fewer postoperative complications, shorter postoperative length of stay, improved quality of life, and reduced declines in functional disability compared to sedentary controls.

Summary
A concentrated 3-month progressive exercise prehabilitation programme consisting of aerobic training at 45–65% of maximal heart rate reserve (%HRR) along with periodic high-intensity interval training (~90% HRR) four times per week, 30–50 minutes per session, is recommended for improving cardiovascular functioning. A strength training programme of about 10 different exercises focused on large, multi-jointed muscle groups should also be implemented twice per week at a mean training intensity of 80% of one-repetition maximum. Finally, a minimum of 140 g (~560 kcal) of carbohydrate (CHO) should be taken 3 h before training to increase liver and muscle glycogen stores and a minimum of about 200 kcal of mixed protein–CHO should be ingested within 30 min following training to enhance muscle hypertrophy.

Keywords
functional capacity, prehabilitation, rehabilitation, surgery

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Abbreviations

CHO	carbohydrate
HRR	heart rate reserve
$\dot{V}O_{2max}$	maximal oxygen uptake
$\dot{V}O_2R$	oxygen uptake reserve

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Introduction

Surgery represents a major stressor for elderly patients, causing loss of muscle mass, deconditioning, hypoxemia, mental disturbances and sleep disorders. Elderly patients – generally unfit and with significant co-morbidities – tend to have more postoperative complications and a longer convalescence than younger patients. It is customary to provide rehabilitation during the post-operative period of convalescence.

Since people are living well into their late 70s and early 80s, they are more likely to require surgery. The annual rate of surgical interventions during the last two decades has almost doubled for men and women 75–84 years of age compared to the middle-aged population. Morbidity and mortality associated with surgery increase with advancing age and rise sharply after the age of 75 [1].

Evaluation of physical status and identification of age-related disease, rather than ageing itself, should be the focus for preoperative assessment and for planning peri-operative care. To optimize organ function in preparation for surgery, the functional reserve has to be assessed and the specific disease process within each organ system identified [2]. The functional reserve represents a safety margin that may be needed to meet increased demands for cardiac output, carbon dioxide excretion, protein synthesis, immune responsiveness, etc. Since the functional reserve decreases with age, any organ system dysfunction places the elderly population at risk. When analysing components of mortality in the elderly population, the probability of death from cardiac, vascular and pulmonary causes increases dramatically in the oldest fractions of the geriatric group, while malignancy and metabolic disorders play a lesser role.

Regular exercise and physical conditioning in elderly populations have been shown to cause positive changes in cardiorespiratory function and other regulatory mechanisms, with associated enhancement of physical performance. Several studies have shown that patients with chronic heart failure who perform long-term endurance training have increased functional capacity, lower risk of mortality, greater quality of life and greater muscle strength [3–5]. Postoperative exercise training programmes (rehabilitation) on cancer survivors [6] also demonstrate that exercise improves a wide range of biopsychosocial outcomes. However, few studies have focused on presurgical exercise training (prehabilitation) to enhance functional capacity in elderly patients. Therefore, based on previous literature presented on presurgical exercise training, a programme of prehabilitation is proposed in order to enhance functional exercise capacity in the elderly population with the intent to minimize the postoperative morbidity and accelerate postsurgical recovery.

Physiological adaptations to exercise in the elderly population

The cardiovascular and musculoskeletal systems are central to achieving and maintaining functional independence, which is a prerequisite for discharge from a health-care facility, as is independent functioning of the individual in the community setting [7].

Cardiovascular adaptations

It has been shown that maximal oxygen uptake ($\dot{V}O_{2max}$), which is a widely used parameter characterizing the effective integration of the central nervous, cardiopulmonary and metabolic systems and remains a reliable measure of aerobic conditioning, can improve by 20–30% in response to 6–12 months' training in previously sedentary older women and men [7,8•,9,10].

However, there is a heterogeneity of the training response as gains in $\dot{V}O_{2max}$ can range anywhere from 0 to 1 l min^{-1} with a coefficient of variation of about 8% (202 ml min^{-1}) [8•]. The increase in $\dot{V}O_{2max}$ with endurance training has been associated with a decrease in maximum heart rate of 3–7% [9], independent of age, and due in part to the larger stroke volume [9,10].

In elderly males, two-thirds of the increase in $\dot{V}O_{2max}$ in response to endurance training is accounted for by the increase in maximal cardiac output, while one-third is due to wider arteriovenous oxygen difference at maximal exercise [11]. In contrast, the increase in $\dot{V}O_{2max}$ from endurance training in elderly women has been shown to be solely a result of enhanced arteriovenous oxygen difference at maximal exercise, implying that there are no real central adaptations to exercise training in elderly women [11]. There are also modest improvements in aerobic capacity with short-term training. In fact, training at 70% of $\dot{V}O_{2max}$ for 1 h per day, four times per week for four weeks can improve maximal oxygen uptake by 6.6% and reduce submaximal heart rate by 10 beats per minute [12]. This suggests rapid cardiovascular improvements in elderly people over a short period [13].

Since endurance-trained adults appear to undergo greater rates of decline in $\dot{V}O_{2max}$ with advancing age compared with sedentary adults [14•], one may presume that endurance training throughout the lifespan may not be beneficial. However, endurance-trained older individuals are able to perform physical tasks that cannot be performed by their sedentary peers, at least with the same degree of exertion or effort [14•]. This is possible because endurance-trained older individuals possess higher levels of aerobic capacity compared to their sedentary peers of the same age. And, since $\dot{V}O_{2max}$ is a more powerful predictor of mortality than other established risk factors for cardiovascular disease [15], and because age and bed rest contribute to a decrease in $\dot{V}O_{2max}$, it seems intuitive to have patients – especially the elderly patient population – perform aerobic exercise training. As disease progresses prior to surgery, elderly patients can become more incapacitated and deconditioned, thus being unable to perform simple tasks without becoming dyspneic and fatigued. Therefore, improving $\dot{V}O_{2max}$ in elderly persons prior to surgery should be beneficial. In particular, a 1 MET (Metabolic equivalent = 3.5 ml kg^{-1} min^{-1}) increase in $\dot{V}O_{2max}$ confers a 12% increase in survival [15], further establishing the validity of aerobic exercise training prior to surgery to improve outcome.

Musculoskeletal adaptations

Ageing is associated with a progressive reduction of muscle tissue volume [16,17] and a concomitant reduction in strength [18], but it is unclear whether this diminution causes the corresponding age-related decreases in bone mineral density [19]. The reduction in muscle tissue, and thus strength, worsens daily functional ability of elderly persons. However, it has been shown that resistance training can counteract the atrophy and loss of strength in this age group [20,21,22••], potentially improving coordination, balance and perhaps bone mineral density. Relative muscle strength can be increased by 20 to ∼200% by weight training [23–29], even after the age of 80 years [19]. This is larger than the corresponding increase in muscle mass. Tracy and colleagues [30] have nicely shown that elderly individuals can improve quadriceps muscle strength by 27%, corresponding to a 12% increase in muscle mass, after 9 weeks of weight training. A large part of the increase in strength is not only from increases in cross-sectional area of muscle, but also due to a neural component. In addition, a recent review has suggested that the magnitude of the exercise-induced muscle response is far greater than the corresponding response in bone mineral density [29,31]. For example, high-impact weight training only results in about a 1% increase in bone mineral density of femoral neck and spine in postmenopausal women [32]. Excellent reviews on the control of the size of human muscle mass and human muscle turnover in elderly people are presented elsewhere [33•,34••].

Previous studies of prehabilitation

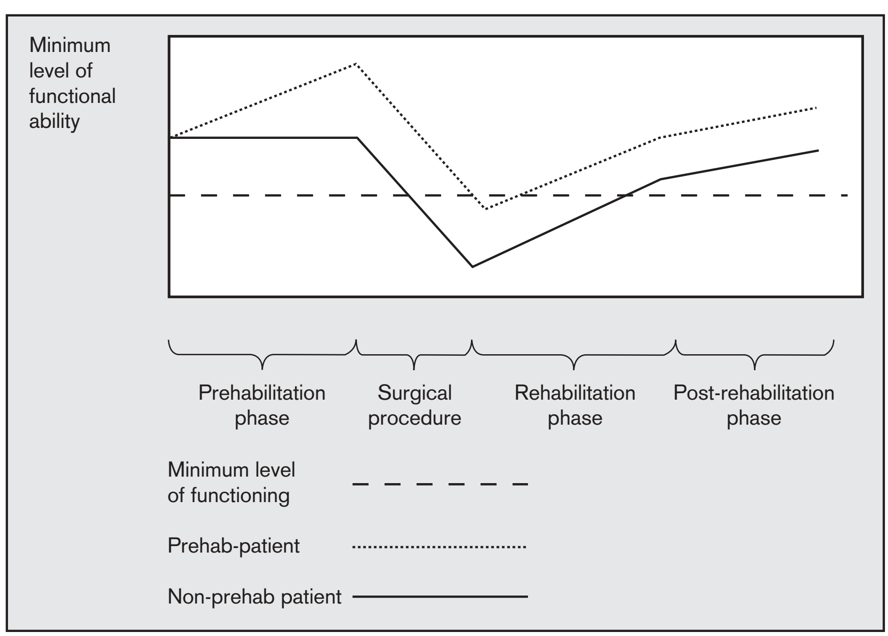
A decline in physical activity among surgical patients represents a significant health risk that may be reduced through introducing exercise prehabilitation interventions. It is reasonable to assume that increasing patients' functional capacity through increased physical activity prior to a surgical admission (as opposed to after the operation) would allow them to retain a higher level of functional capacity over their entire surgical admission, with an increase in quality of life. Preoperative assessment of fitness has been used to assess outcomes from surgery [35,36], along with measures of quality of life [37], mobility [38] and pain/stiffness [39,40]. Poor fitness scores preoperatively have been shown to increase the chance of dying within 30 days post surgery [35], or at least result in a significantly longer stay in hospital postoperatively [36], with greater chance of surgical complications [35,36]. Furthermore, it has been shown that in elderly patients with osteoarthritis, those with worse preoperative quality of life and physical function continue to have more pain and worse function postoperatively than their counterparts with better preoperative functional status [41]. Therefore, enhancing functional capacity prior to surgery seems important to improve quality of life, reduce postoperative pain and postsurgical complications, increase functional capacity and decrease mortality.

The process enabling patients to withstand the stressor of inactivity associated with an admission to surgery though augmenting functional capacity is termed 'prehabilitation' (as opposed to rehabilitation, which is enhancing functional capacity after injury or post surgery). Topp *et al.* [7] and Ditmyer *et al.* [42] have proposed that by applying a presurgical exercise programme in patients to improve functional ability before a stressor such as surgery, postoperative recovery and achievement of a minimal level of functional ability would occur more rapidly compared to patients who remain inactive through the whole surgical admission (Fig. 1). Of all age groups, the elderly population have the most to gain by being active throughout the surgical admission, since functional capacity is already diminished due to the ageing process. Compounded by a sedentary lifestyle, bed rest further reduces musculoskeletal strength and $\dot{V}O_{2max}$ in these elderly patients, further reducing functional capacity.

The theory of prehabilitation was initially supported in animal models. To investigate the effect of voluntary exercise on the tolerance to trauma, female rats kept in cages with running wheels for 3–7 weeks (exercise group) were subjected to trauma and compared to rats kept in cages without running wheels for the same period (sedentary group) [43]. Mortality was significantly decreased in rats kept in cages with running wheels for 5 weeks or 7 weeks. These results indicated that voluntarily exercising rats showed increased resistance to trauma as compared to rats kept under the sedentary condition. Rats who sustained bilateral removals of

Figure 1. Trajectory of functional ability throughout the surgical process with and without preoperative exercise training (prehabilitation)

Adapted with permission [7] and [42].



sensorimotor cortex recovered faster compared to control rats if they were exposed to high levels of physical activity (running wheel) 2 h per day, 25 days before surgery [44]. This suggests that the preoperative opportunity for exercise enhanced motor capabilities, facilitating recovery. Do these animal data (and does the theoretical model of prehabilitation proposed by Topp *et al.* and Ditmyer *et al.*) apply to the surgical patient population? There have been relatively few studies looking at the benefits of presurgical exercise programmes in elderly humans (Table 1). Using a data-set of about 717 elderly patients from various studies, we sought to examine the effects of pre-exercise training on postsurgical outcome measures in individuals undergoing orthopaedic surgery (knee and hip) [46,47,49,59]. abdominal [45] and cardiac surgery [53]. The data suggest that prehabilitation prior to orthopaedic surgery does not improve health-related quality of life or recovery. In contrast, prehabilitation prior to abdominal or cardiac surgery results in fewer postoperative complications, shortens time of stay in hospital post surgery, improves health-related quality of life, and can reduce declines in functional disability compared to control groups. Clearly, while the results look promising in patients undergoing abdominal or cardiac surgery, more research needs to be conducted.

The exercise prehabilitation programme

The presurgical exercise programme should consist of both strength and aerobic training [5,61–63] as well as some stretching exercises [7,42]. Aerobic and muscular strength training in elderly patients increases endurance capacity [23], reduces weight gain [62], improves muscle strength [22••], reduces fall risk [64] and increases range of motion in a number of joints [62]. There are contraindications to exercise but they have been clearly laid out elsewhere [65] and will not be discussed further.

Rationale for the aerobic training prehabilitation programme

Our aerobic exercise prescription is primarily based on the American College of Sports Medicine (ACSM) Guidelines for Exercise Testing and Prescription [65] and the most recent ACSM Position Stand [66] but includes modifications from recent literature [67]. Training intensities are based on percentage of heart rate reserve (HRR) [68], which has been shown to be similar to $\dot{V}O_2$ reserve ($\dot{V}O_2R$) [69]. For a complete description of training intensities, see Table 2. According to Swain [67], individuals who are classified as having low initial fitness ($\dot{V}O_{2max} < 40$ ml kg^{-1} min^{-1}) based on a graded exercise test to maximum will show improvements in functional capacity only if the training intensity is $\geqslant 30\%$ $\dot{V}O_2R$. For those with a higher aerobic capacities ($\dot{V}O_{2max} > 40$ ml kg^{-1} min^{-1}), the minimal training intensity has to be $\geqslant 45\%$ $\dot{V}O_2R$. Since

Table 1. Studies which have used exercise training (aerobic, musculoskeletal or both) prior to surgery to speed recovery, enhance functional capacity and improve morbidity and mortality in 717 elderly patients

Study	Number of patients in control group	Number of patients in exercise group	Mean age (years)	Mean weight (kg)	Type of surgery	Exercise programme before surgery in the treatment group	Measurement scales used	Outcome/conclusion
Asoh and Tsuji [45]	18	11	68.0	NM	Abdominal surgery	Aerobic training sessions 20 min in duration, on a bike or treadmill, twice per day for 1–3 weeks at a HR not above 130 beats/min	Incidence of postoperative complications and death	There were fewer postoperative complications and deaths in the preoperative exercise group compared to control groups
Weidenhielm *et al.* [46]	20	19	64	87	Total knee replacement	Strength and mobility training three times per week for 5 weeks. Strength training involved lifting the leg unloaded against gravity and held in the air horizontally for 10 s. Mobility training involved flexion and extension of the knee in supine and sitting positions	Thigh muscle strength via isokinetic dynamometer; walking speed; pain via a four-point Likert scale	Preoperative training did not improve thigh muscle strength, but maximal walking speed increased and pain was slightly decreased. Such improvements were not seen in the control group
Wijgman *et al.* [47]	33	31	65	NM	Total hip arthroplasty	30-min sessions of mobility exercise involving hip extensor, abductors and knee extensors	Visual Analogue Scale; Harris Hip Score [48]	Preoperative exercise and instruction is not useful for patients who, in the near future, will be treated with a total hip arthroplasty for primary coxarthrosis

Table 1. (*continued*)

Study	Number of patients in control group	Number of patients in exercise group	Mean age (years)	Mean weight (kg)	Type of surgery	Exercise programme before surgery in the treatment group	Measurement scales used	Outcome/conclusion
D'Lima *et al.* [49]	10	10	70.6	82.0	Total knee replacement	One group performed aerobic training three times per week at 45 min per session for 6 weeks at 40–70% HRR on a bike; another group performed strength training three times per week at 45 min per session of isometric and isotonic exercise	Hospital for Special Surgery Scale [50]; Arthritis Impact Measurement Scale [51]; Quality of Well Being [52]	Neither aerobic nor strength training pre-surgery added to the degree of improvement after surgery as measured by the three measurement scales compared to the control (non-exercise group)
Arthur *et al.* [53]	123	123	62.8	NM	Coronary artery bypass graft surgery	Aerobic training twice per week at 40–70% HRR on a bike, for 8.3 weeks. Exercise was on treadmill, and/or stair climbers for 90 min total that included warm-up, stretching, aerobic intervals (30-min), and cool-down	SF-36 for health-related quality of life [37]; $\dot{V}O_{2max}$; length of hospital stay post surgery	Actual time spent in the ICU was 2 days shorter, time spent in the hospital after surgery was 1 day shorter and total time spent in hospital was 1 day shorter in the preoperative exercise group compared to controls. SF-36 subscale improved during the waiting period and 6 months post surgery in the preoperative exercise group compared to control group
Gill *et al.* [54,55]	94	94	83.2	N/A	No surgery	12-month, home-based training programme. Balance exercises once per day, strength conditioning exercises three times per week	Instrumental activities of daily living (IADLs) [56,57]; physical performance test (PPT) [58]; mobility assessment [38]	Compared with the control group, the exercise intervention group had reductions in IADL disability by 18% at 7 months and 12% at 12 months, and had gains of 7–15% in mobility and physical function. Functional disability and decline can be slowed with this intervention
Beaupre *et al.* [59]	66	65	68.0	BMI = 31.5	Total knee arthroplasty	Strength training three times per week for 4 weeks, 30 min per session. Three sets of 10 repetitions initially, increased to three sets 15 repetitions later. No description of exercises	WOMAC index for pain, stiffness and function measures; SF-36 for health-related quality of life [40,60]	The exercise intervention did not alter functional recovery of health-related quality of life compared to control group during the 1-year postoperative interval
Weighted mean ± SD	**52 ± 43**	**50 ± 45**	**70.2**				**Summary (based on these limited data)** A. Prehabilitation prior to orthopaedic surgery (four studies) does not seem to improve health-related quality of life or recovery B. Prehabilitation prior to abdominal or cardiac surgery (two studies) results in fewer postoperative complications, shortens time of stay in hospital post surgery, improves health-related quality of life and can reduce declines in functional disability compared to control groups	

NM, not mentioned. Please note that Gill and colleagues [54,55] were included in the table because they used the term 'prehabilitation' in their article titles; however, there was no postoperative surgical assessment in their patients. Nevertheless, there are some interesting data that are applicable to postsurgical recovery and so they remained in the table.

Table 2. Classification of physical activity intensity

	Endurance-type activity							Resistance-type exercise
	Relative intensity			Absolute intensity (METs) in healthy adults (age in years)				Relative intensity*
Intensity	$\dot{V}O_2R$ (%) heart rate reserve (%)	Maximal heart rate (%)	RPE†	Young (20–39 yr)	Middle-aged (40–64 yr)	Old (65–79 yr)	Very old (80+ yr)	Maximal voluntary contraction (%)
Very light	<20	<35	<10	<2.4	<2.0	<1.6	$\leqslant 1.0$	<30
Light	20–39	35–54	10–11	2.4–4.7	2.0–3.9	1.6–3.1	1.1–1.9	30–49
Moderate	40–59	55–69	12–13	4.8–7.1	4.0–5.9	3.2–4.7	2.0–2.9	50–69
Hard	60–84	70–89	14–16	7.2–10.1	6.0–8.4	4.8–6.7	3.0–4.25	70–84
Very hard	$\geqslant 85$	$\geqslant 90$	17–19	$\geqslant 10.2$	$\geqslant 8.5$	$\geqslant 6.8$	$\geqslant 4.25$	$\geqslant 85$
Maximal‡	100	100	20	12.0	10.0	8.0	5.0	100

*Based on 8–12 repetitions for persons under age 50–60 years, and 10–15 repetitions for persons aged 50–60 years and older.
†Borg Rating of Perceived Exertion 6–20 scale [70].
‡Maximal values are mean values achieved during maximal exercise by healthy adults. Absolute intensity (METS) values are approximate mean values for men. Mean values for women are approximately 1–2 METS lower than those for men. $\dot{V}O_2R$, oxygen uptake reserve.
From the most recent American College of Sports Medicine Position Stand [66], reprinted with permission.

almost all elderly patients have low initial fitness levels, 45% HRR (which is the same as 45% $\dot{V}O_2R$) is the starting point for our prehabilitation programme. Keep in mind that the 2-day coefficient of variation for $\dot{V}O_{2max}$ is about 4.3% before training and 3.4% after training [8•]. Consequently, the measurement error of $\dot{V}O_{2max}$ from pre to post training would contribute to a coefficient of variation of about 5.5% to apparent training responses, or about 132 mL min^{-1} [8•]. Also, there is a heterogeneity of the training response [8•], so not all elderly people will improve to the same extent.

To set the length of the prehabilitation programme, we must consider other extraneous variables such as severity of disease, the time interval allowed prior to operation and the patients' motivation and willingness to participate. Given that these can be controlled, the duration should be a minimum of 4 weeks, but preferably longer – up to 3 months. Research has shown that 3 months of endurance training are required to provide a clinically meaningful increase in vagal modulation of the sinus node, modest reduction in blood pressure from reduced vascular resistance and an increase in $\dot{V}O_{2max}$ [71]. The greatest change in these variables occurred in the first 3 months of training, and lengthening the training programme or increasing the intensity of the training programme (based on a training impulse score [72]) did not substantially improve these variables further [71]. However, recent data have shown that intense intermittent endurance training (about 90–150% of $\dot{V}O_{2max}$) for very short periods of time (1 minute's exercise, 3 minutes' rest) to recruit more fast twitch fibres induces capillary growth (new blood vessels) in fast twitch fibres [73]. Taking into consideration these data, the 3-month aerobic prehabilitation programme presented in Table 3 includes progressively increasing intensities (45–65% $\dot{V}O_2R$) to augment oxygen transport and high-intensity exercise later on (90% $\dot{V}O_{2max}$ which is about 85% $\dot{V}O_2R$) to allow for an angiogenic effect on muscle capillarization and to reduce the amount of energy derived anaerobically.

Rationale for the strength training prehabilitation programme

Age-related declines in muscle strength are directly related to sarcopenia (loss of skeletal muscle mass) [17]. Since total muscle cross-sectional area decreases by ~40% between the ages of 20 and 60 years [74,75], strength training should be implemented to prevent this decline. A recent national survey indicates that only about 12% of elderly individuals (65–74 years) and 10% of individuals aged $\geqslant 75$ years perform regular strength training [76], which may contribute to the age-related decline in muscle mass. Thus, strength training should be implemented in elderly people because of its positive effects on their functionality, health and quality of life [77–79]. If elderly people are properly supervised, shown how to use the equipment and taught the appropriate techniques, then there is no reason why weight training should not be implemented given the huge potential benefit that certainly outweighs any minimal risk.

Our strength-training prescription is primarily based on the American College of Sports Medicine (ACSM) Guidelines for Exercise Testing and Prescription [65] and the most recent ACSM Position stand [66] but includes modifications from recent literature [22••,80••,81••]. A recent meta-analysis on untrained individuals showed that the best gain in strength is achieved by moderate-intensity weight training, or about 60% of one-repetition maximum (%1-RM), at a frequency of 3 days per week [80••]. One-repetition

Table 3. A progressive prehabilitation programme for the elderly surgical population

Component of physical fitness	Frequency	Duration, intensity and RPE for weeks 1–2	Progression
Cardiovascular training	Mon, Wed, Thu (steady-state aerobic training)	20 min, 45% HRR, 12 RPE	Weeks 3–4: 30 min, 55% HRR, 13 RPE Weeks 5–6: 35 min, 65% HRR, 15 RPE Weeks 7–8: 40 min, 65% HRR, 15 RPE Weeks 9–12: 45 min, 65% HRR, 15 RPE
	Sat (aerobic intervals)	24.5 min total or seven sets of 30 s at 85% HRR with 3 min rest between sets at 30% HRR, 17 RPE	Weeks 3–4: 37.5 min total or 10 sets of 45 s at 90% HRR with 3 min rest between sets at 30% HRR, 17 RPE Weeks 5–6: 48 min total or 12 sets of 1 min at 95% HRR with 3 min rest between sets at 30% HRR, RPE 19 Weeks 7–8: 48 min total or 12 sets of 1 min at 100% HRR with 2.5 min rest between sets at 30% HRR, RPE 20 Weeks 9–12: 48 min total or 12 sets of 1 min at 100% HRR with 2 min rest between sets at 30% HRR, RPE 20
Strength training	Tue	45 min, 60% of 1-RM (15 reps per set), 1 min rest between sets, three sets per exercise, 14 RPE or 4 on the CR-10 scale [83]. Exercises are lower body multi-joint: machine leg press, machine hamstring curl, lunges Upper body multi-joint: machine bench press, upright seated row, push-ups or modified push-ups, machine or dumbbell military press Upper body single-joint: front deltoid raise with books, dumbbell biceps curls, sit-ups (abdominal crunches)	Weeks 3-4: 45 min, 70% of 1-RM (11 reps per set), 1 min rest between sets, three sets per exercise, 15 RPE or 5–6 on the CR-10 scale [83]. Same exercises on Tue and Fri Weeks 5–6: 50 min, 80% of 1-RM (eight reps per set), 1 min rest between sets, four sets per exercise, 16 RPE or 6–7 on the CR-10 scale [83]. Same exercises on Tue and Fri Weeks 7–8: 50 min, 85% of 1-RM (six reps per set), 1 min rest between sets, four sets per exercise, 17 RPE or 7 on the CR-10 scale [83]. Same exercises on Tue and Fri
	Fri	45 min, 60% of 1-RM (15 reps per set), three sets per exercise, 14 RPE or 4 on the CR-10 scale [83]. Exercises are lower body multi-joint: step-ups, machine hamstring curl, lunges Upper body multi-joint: machine incline bench press, push-ups or modified push-ups, latissimus pulldown, seated row Upper body single-joint: triceps extension, barbell biceps curl, sit-ups (abdominal crunches)	Weeks 9–12: 50 min, 85% of 1-RM (six reps per set), 1 min rest between sets, four sets per exercise, 17 RPE or 7 on the CR-10 scale [83]. Free weights should be implemented to replace machine weights (i.e. bench press), for lunges add dumbbells. For sit-ups, progress to a stability ball
Flexibility		Performed after warm-up every session. Static stretches of about 20–30 s for the hamstrings, quadriceps, deltoids and back should be implemented	

Sundays are rest days. Although not listed above, a 5–10 min warm-up of low-intensity progressive aerobic activity (30%HRR) followed by 5–10 min of stretching and callisthenic-type activity should precede training [65]. An appropriate cool-down should follow training [65]. The inclusions of flexibility exercises are also important, but it is not the focus of this review. The reader is encouraged to look elsewhere [65]. The mode of exercise for improving aerobic capacity should involve the use of large muscle groups, and be rhythmic in nature. As such, walking, jogging on a treadmill or biking on a stationary cycle ergometer is recommended. A RPE scale of 6–20 is used to subjectively determine training intensity [70], which has also been validated using a modified version for strength training [83]. The calculation of aerobic training intensity is based on heart rate reserve (%HRR) which requires the knowledge of the patient's resting and maximal heart rate [65,68]. Resting heart rate should be directly measured with a heart rate monitor or ECG by averaging the heart rate from the last 5 of 10 min of upright chair sitting. It is our opinion that maximal heart rate should be measured directly from a $\dot{V}O_{2max}$ test, as the '220 minus age' prediction has a standard deviation of $\pm$10 beats per minute in the population, which is too large for accurately prescribing training intensity based on the %HRR method. Predicting or directly measuring 1-RM and the description of each exercise is described nicely elsewhere [82]. A conservative method to increase training load is called the 2-for-2 rule [82]. If the individual can perform two or more repetitions over the assigned repetition goal in the last set in two consecutive workouts for a certain exercise, weight should be added to that exercise for the next training session. The estimate load increase is 2.5–5 lb for the upper body and 5–10 lb for the lower body [82]. As mentioned in this paper, pre ($\sim$3 h before) and post (immediately) exercise feeding is very important for glycogen synthesis and muscle hypertrophy and should be followed in the elderly population performing prehabilitation.

maximum (1-RM) is the greatest amount of weight that can be lifted once with the proper technique before the onset of fatigue prohibits further repetitions. An intensity of 60% of 1-RM equates to about 15 repetitions until fatigue [82]. The most appropriate volume was determined to be four sets per muscle group per workout [80••] and the dose–response curves were similar for all ages.

The strength-training prescription for the untrained should be different compared to a strength-training prescription for athletes [81••]. A meta-analysis examining strength gains in athletes has also demonstrated a distinct dose–response relationship for strength development, with the largest gains in strength shown at higher intensities and volumes (85% of 1-RM, which is about six repetitions to fatigue, approximately eight sets per muscle group per workout) and the lowest gains in strength shown at lower intensities and volumes (50 to 70% of 1-RM, one to three sets per muscle group per workout) [81••]. Also, the meta-analysis showed that strength training in athletes twice per week is just as effective as three times per week [81••], which is less frequent than was found effective with the untrained [80••].

There are some conflicting results. Very recent work has shown that high-intensity strength training (80% of 1-RM) achieves larger gains in strength and muscle hypertrophy in elderly patients than does moderate-intensity strength training (60% of 1-RM) [22••], which was not listed in the previous review on the untrained patients [80••]. It seems, then, that there is some continuum between 60 and 85% of 1-RM that may be appropriate in strength-training programmes in elderly people. In fact, when scrutinizing the data, there is only a slight difference in treatment effects between 60% (2.8 ± 2.3), 80% (2.0 ± 3.3) and 85% (1.6 ± 2.7) of 1-RM in the untrained, and there is also a slight difference in treatment effects between training twice per week (1.2 ± 3.1) versus three times per week (1.9 ± 2.3) [80••].

In light of the information reported above, the following progressive prehabilitation strength-programme guidelines for resistance training are recommended for elderly people. A minimum of eight to ten different exercises involving the major, multi-jointed muscle groups (arms, shoulders, chest, abdomen, back, hips and legs) should be performed, 2 days per week on non-consecutive days, and preferably with 72 h recovery between sessions. The volume that we recommend is four sets per exercise, starting at an intensity of ~80% of 1-RM (about eight repetitions to fatigue per exercise), which should be completed by most patients; however, for older and more frail persons, ~60% of 1-RM (15 repetitions to fatigue per exercise) may be more appropriate and prudent. The determination of 1-RM can be measured directly, or estimated through submaximal measures described elsewhere [82]. Monitoring the intensity of strength training can be done reliably with using ratings of perceived exertion [70,83]. Machine weights should be used initially, with the objective that free weights would replace machine weights when familiarity, technique and skill of weight training are improved. If possible, programme supervision by a Certified Strength and Conditioning Specialist®, physiotherapist or related professional would benefit elderly patients by improving safety and exercise adherence. See Table 3 for the prehabilitation programme.

Rationale for a nutritional component to prehabilitation

Recent research on elderly patients has shown that it matters considerably when a person eats a protein meal after weight training [84,85]. Recent research has shown that elderly individuals (74 years) who consume 10 g protein, 7 g carbohydrate (CHO) and 3 g fat in a power-bar-type supplement *immediately* (within 30 min) after weight training increased mean quadriceps fibre area by 24%, increased cross-sectional area of quadriceps by 8% and increased dynamic muscular strength by 46% after a 12-week, three times per week resistance-training programme [85]. Conversely, another group who did the identical exercise routine but waited until 2 h post exercise before consuming the supplement did not show any increase in muscle hypertrophy and only increased dynamic muscular strength by 36% [85]. More recent data have shown a similar added effect of long-term nutrition supplementation on grip strength and inspiratory pressure training to decrease the respiratory complications in elderly people [86]. These data suggest that weight training with the immediate consumption of ~100 kcal protein-CHO post exercise improves muscle protein synthesis and thus hypertrophy in elderly individuals. Finally, a minimum of 140 g (~560 kcal) CHO should be taken 3 h before exercise, to increase liver and muscle glycogen stores and enhance the likelihood of completing the exercise session [87].

Conclusion

Implementing a presurgical exercise programme to enhance functional capacity, speed recovery post surgery, reduce mortality and improve quality of life in elderly people is an intriguing concept that could have an enormous effect on reducing health-care costs. From the limited data presented, is seems that prehabilitation is beneficial in elderly patients undergoing abdominal or cardiac surgery, since it is the elderly who are especially affected by bed rest and lack of exercise due to their already low functional capacity. However, more studies on the effect of prehabilitation on outcome measures need to be conducted. A prehabilitation exercise-programme template has been provided, based on recent scientific literature.

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