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HOW I DO IT

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Steep ramp test protocol for preoperative risk assessment and short-term high-intensity interval training to evaluate, improve, and monitor cardiorespiratory fitness in surgical oncology

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1 | INTRODUCTION

Preoperative risk assessment and prehabilitation in routine clinical practice in the field of surgical oncology are receiving increasing attention. Timely recognition of patients at high risk for adverse surgical outcomes (e.g., complications, delayed recovery of physical functioning) using preoperative risk assessment is fundamental to further improving patient- and treatment-related outcomes. Preoperative risk assessment supports shared decision-making, facilitates surgical preparation, and may guide postoperative care.[1] Preoperative cardiorespiratory fitness is independently associated with postoperative complications, length of hospital stay, and mortality of patients who are scheduled to undergo major abdominal surgery,[2,3] thus signifying its importance as a risk assessment tool. Exercise prehabilitation is known to improve preoperative cardiorespiratory fitness; however, its effects on postoperative outcomes are inconsistent.[4–7] Previously published randomized clinical trials have demonstrated that prehabilitation for certain high-risk patients significantly improves their outcomes after major abdominal surgery.[8,9]

The cardiopulmonary exercise test (CPET), during which exercise intensity and, consequently, metabolic demand increase gradually from rest to maximal volitional exhaustion, is the gold standard for assessing cardiorespiratory fitness. Although oxygen uptake during peak exercise at maximal effort (VO_{2peak}) is considered the primary outcome of the CPET, oxygen uptake at the ventilatory anaerobic threshold and the oxygen uptake efficiency slope are valuable submaximal indicators when patients are unable or unwilling to perform at maximal effort.[10,11] VO_{2peak}, oxygen uptake at the ventilatory anaerobic threshold, and oxygen uptake efficiency slope, as determined by the CPET, provide information about a patient's cardiorespiratory fitness and capacity to cope with increased metabolic demand after major surgery. Moreover, the CPET provides information about dominant exercise limitations, possible contraindications to physical exercise training, personalized physical exercise training prescriptions, and the effects of interventions on cardiorespiratory fitness. Therefore, its use is recommended to assess the preoperative risk and support shared pre- and postoperative decision-making.[12] However, the CPET requires specific equipment, trained staff, and expertise. Additionally, because of its associated time investment and cost, its preoperative use is impossible in a resource-constrained environment; therefore, it is often limited to research settings. To enable the widespread implementation of a preoperative evaluation of cardiorespiratory fitness and prehabilitation for high-risk patients, an accurate and practical field test that can evaluate cardiorespiratory fitness is urgently needed. Furthermore,

this field test should be feasible for unfit patients, such as elderly individuals, and applicable in community- and home-based settings to allow the personalization of preoperative physical exercise training and cardiorespiratory fitness monitoring.

2 | SOLUTION

A modified version of the steep ramp test (SRT) was developed as a practical and objective field test to evaluate preoperative cardiorespiratory fitness and guide short-term high-intensity interval training (HIIT) to preoperatively improve the cardiorespiratory fitness of individual patients in routine clinical practice.

2.1 | Steep ramp test

The SRT is a short-term easy-to-use maximal field test that uses a cycle ergometer and does not require respiratory gas analysis measurements, thus making it suitable for routine clinical practice. The SRT was developed to determine and optimize the interval training intensity of adult patients with heart failure.[13] Originally, the protocol consists of 3 min of unloaded cycling; thereafter, the work rate is rapidly increased by 25 W every 10 s until peak exercise, which is defined as the point at which the patient is unable to maintain a pedaling frequency ≥60 revolutions/min.[13] The work rate at peak exercise (WR_{peak}) is the primary outcome. The SRT is a valid tool for assessing the cardiorespiratory fitness of cancer survivors because the SRT WR_{peak} is strongly correlated with the CPET VO_{2peak} ($r = 0.82$ and $r = 0.86$, respectively).[14,15] Compared with the CPET, the SRT protocol results in a higher WR_{peak} (162% of the CPET WR_{peak})[14] and a significantly shorter work rate increment phase (SRT: 1:30 min; CPET: 9:49 min),[15] thus indicating its brief and supramaximal nature. Moreover, pediatric research has suggested that the SRT is less stressful for the cardiopulmonary system than the CPET as demonstrated by the significantly lower heart rate and minute ventilation values at peak exercise.[16]

The original SRT protocol (25 W/10 s) has been extensively applied preoperatively for unfit and/or elderly patients scheduled to undergo major surgery at our university medical center. However, these patients were often overwhelmed by the speed of the work rate increments despite pretest instructions regarding the test protocol, verbal instructions, and encouragement throughout the test. This frequently resulted in an SRT protocol lasting <30 s and the following reasons for stopping the test: "it went too fast" and/or "I could not keep up." Although all metabolic pathways associated with anaerobic and aerobic energy provisions are activated during short-term intense exercise, the energy provision rates from anaerobic sources are much more rapid than those from aerobic pathways.[17] Therefore, it is unknown whether the use of the SRT performance can provide a valid assessment of cardiorespiratory fitness when the SRT protocol lasts <30 s long. To overcome this problem, the original SRT protocol was modified to increase its duration to >60 s to allow for a more accurate reflection of the cardiorespiratory fitness of the majority of patients who require a preoperative risk assessment before major surgery. Although its duration was increased, the modified SRT protocol maintained its short-term status. Moreover, the aim was to use the results of the SRT to monitor, and adjust personalized short-term HIIT to preoperatively improve cardiorespiratory fitness.

2.2 | Modified steep ramp test

The original SRT protocol was adjusted to meet the abovementioned specific requirements. After the provision of careful pretest instructions regarding its purpose, protocol, and importance of maximal effort, the modified protocol starts with a 2-min warm-up of unloaded cycling; the work rate then increases relatively rapidly by 10 W/10 s until voluntary exhaustion. Throughout the test, the patients are asked to maintain a pedaling frequency of 70–80 revolutions/min. The test ends when the pedaling frequency decreases to <60 revolutions/min despite strong verbal encouragement to ensure maximal effort. This point, defined as peak exercise, is immediately followed by a cool-down of unloaded or low-intensity cycling (Figure 1, Graph A). The primary outcome measure is the achieved WR_{peak} (W), which, similar to the VO_{2peak}, oxygen uptake at the ventilatory anaerobic threshold, and oxygen uptake efficiency slope, must be normalized for body mass (W/kg) to correct for interpatient differences in body size. To more accurately assess the attained WR_{peak}, a ramp version of the protocol (work rate increments of 1 W/s) is recommended (Figure 1, Graph A). Secondary outcome measurements, such as heart rate, peripheral oxygen saturation, blood pressure, reason for stopping, and level of perceived exertion, could provide additional information. However, the SRT provides only an approximate indication of cardiorespiratory fitness. Furthermore, it provides no information concerning the dominant exercise limitation and contraindications for physical exercise training.

2.2.1 | Modified steep ramp test to assess preoperative cardiorespiratory fitness for risk assessment

The preliminary results of an ongoing study investigating the criterion validity and test–retest reliability of the modified SRT for evaluating cardiorespiratory fitness suggest a strong correlation ($r = 0.93$) between preoperative SRT WR_{peak} and preoperative CPET VO_{2peak} among patients scheduled to undergo colorectal surgery ($n = 21$; mean age, 71.9 years; standard deviation, ±5.3 years) (Figure 2). Accordingly, the CPET VO_{2peak} can be estimated based on the modified SRT performance as follows: CPET VO_{2peak} (ml/min) = 9.745 × SRT WR_{peak} (W) − 103.5. The SRT WR_{peak} is equal to 148% of the CPET WR_{peak}, while the peripheral muscle strength is the predominant limitation of SRT performance. Previous studies

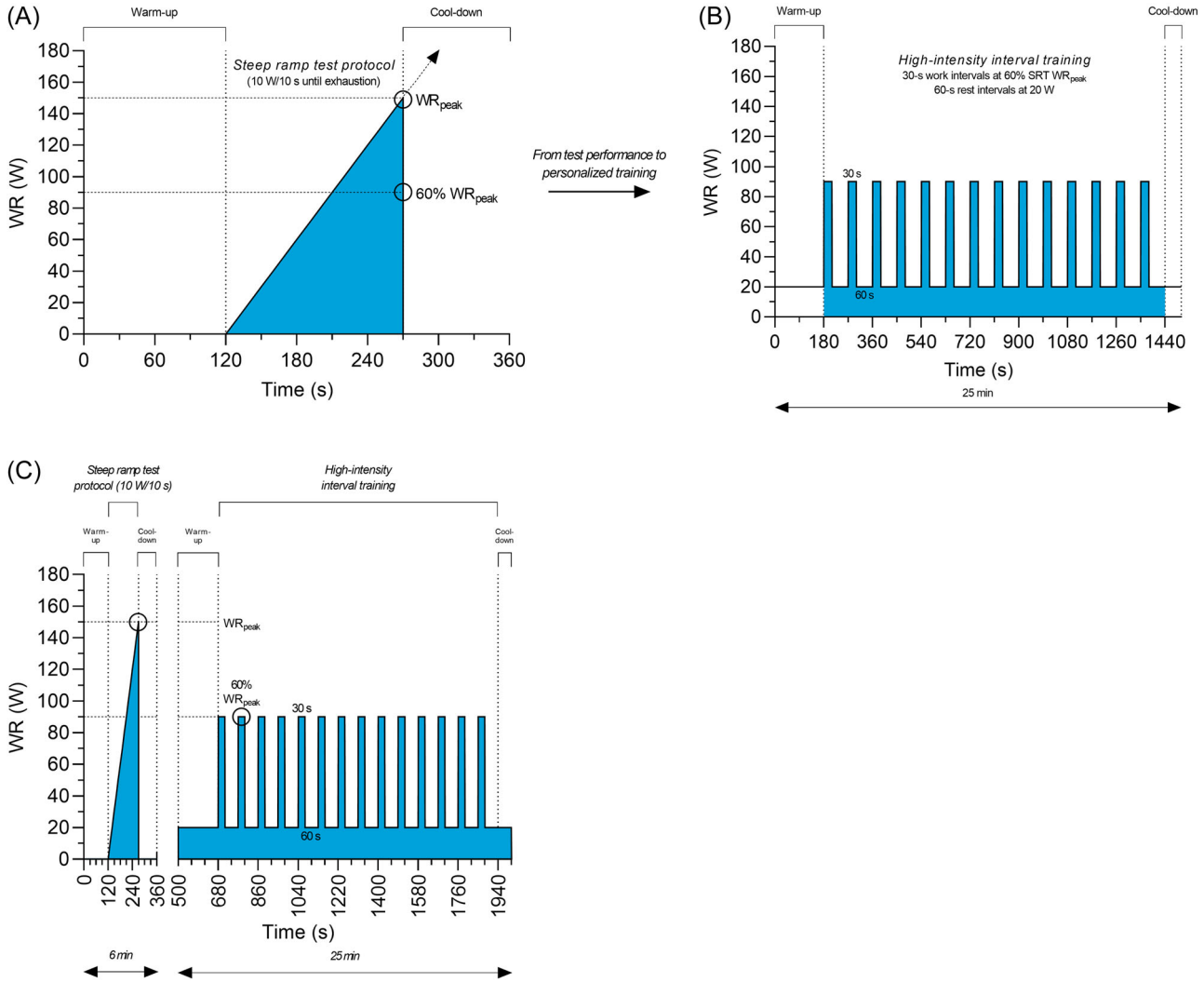

FIGURE 1 From SRT performance to personalized HIIT: outline of the preoperative SRT protocol with an achieved SRT WR_{peak} of 150 W shown as an example (Graph A), the translation from SRT performance to an individualized 25-min HIIT session, consisting of a 3-min warm-up at 20 W, 14 sessions of 30-s high-intensity intervals at an intensity of 60% of SRT WR_{peak} (in the example this corresponds to 90 W) alternated with 60-s low-intensity recovery intervals at 20 W, and a 1-min cool-down at 20 W (Graph B), and a complete overview of the SRT and HIIT protocol for the example (Graph C). HIIT, high-intensity interval training; SRT, steep ramp test; WR, work rate; WR_{peak}, work rate at peak exercise.

reported that preoperative SRT (1 W/s) performance (WR_{peak}, W/kg) is inversely associated with the risk of adverse postoperative outcomes after hepatic,[18] pancreatic,[19] and colorectal resection.[20,21] However, a test-specific cutoff and multivariate predictive model including the SRT performance that can be used to classify patients at low versus high risk for adverse surgical outcomes are lacking; therefore, further research is required.

2.2.2 | Modified steep ramp test to personalize short-term preoperative high-intensity interval training

According to treatment guidelines, the period between the cancer diagnosis and surgery is often only a few weeks. During this short period, HIIT resulted in improvements in cardiorespiratory fitness that were superior to those attained with moderate-intensity exercise training.[22] Thus, a 4-week SRT-based HIIT program was specifically developed to increase the preoperative cardiorespiratory fitness levels of (high-risk) patients scheduled to undergo cancer surgery. After the baseline modified SRT is conducted (Figure 1, Graphs A and C), the partially supervised program including three 25-min HIIT sessions per week can be performed in the patient's living environment (community- or home-based). Every training session comprises a 3-min warm-up at 20 W, 14 sessions of 30-s high-intensity intervals at an intensity of 60% of the SRT WR_{peak} alternated with 60-s low-intensity recovery intervals at 20 W, and a 1-min cool-down at 20 W (Figure 1, graphs B and C). The training intensity during high-intensity intervals corresponds to approximately 90% of the CPET WR_{peak}. The training progression should be objectively measured by weekly or biweekly repetition of the SRT so

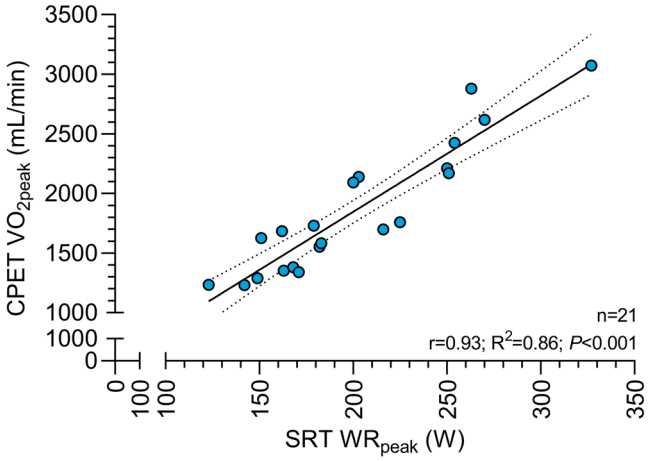

FIGURE 2 Preliminary unpublished data demonstrating the linear relationship between the WR_{peak} attained at the SRT (10 W/10 s) and the VO_{2peak} achieved at the CPET in patients before colorectal surgery, with the linear regression line plotted together with its 95% confidence limits: CPET VO_{2peak} (ml/min = 9.745 × SRT WR_{peak} (W) – 103.5. CPET, cardiopulmonary exercise test; SRT, steep ramp test; VO_{2peak}, oxygen uptake at peak exercise; WR_{peak}, work rate at peak exercise.

to monitor changes in cardiorespiratory fitness, while the program can be adjusted accordingly to maintain a sufficient training stimulus. This partially supervised preoperative SRT-based HIIT program was deemed feasible (82.5% adherence rate, 57.6% full completion rate, 11.5% dropout rate, no serious adverse events, high patient satisfaction) and effective (improvements of 17.2% and 17.8% in VO_{2peak} and oxygen uptake at the ventilatory anaerobic threshold, respectively) for preoperatively increasing the cardiorespiratory fitness of high-risk patients who are scheduled to undergo hepatopancreatobiliary surgery ($n = 26$).[23] This program is currently being investigated to determine its usefulness for other populations requiring major surgery.

3 | CONCLUSIONS

The modified SRT seems an accurate, feasible, and practical field test that can evaluate the cardiorespiratory fitness of patients scheduled to undergo major surgery. This short-term, supramaximal test does not require respiratory gas analysis measurements and is less demanding on the cardiopulmonary system than the CPET. Therefore, its widespread implementation for preoperative risk assessment is appealing. Furthermore, it can be used in community- or home-based settings, and patients can receive personalized preoperative HIIT and cardiorespiratory fitness monitoring before major surgery. Additionally, the short-term SRT-based HIIT program can improve the preoperative cardiorespiratory fitness of high-risk patients who are scheduled to undergo major surgery. These promising findings require further investigation before implementation in routine clinical practice.

DATA AVAILABILITY STATEMENT

The data that support the findings of this manuscript are available from the corresponding author upon reasonable request.

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