AMERICAN COLLEGE of SPORTS MEDICINE
PRONOUNCEMENT

Physical Activity and Exercise Intensity Terminology: A Joint American College of Sports Medicine (ACSM) Expert Statement and Exercise and Sport Science Australia (ESSA) Consensus Statement

DAVID J. BISHOP[1], BELINDA BECK[2,3], STUART J. H. BIDDLE[4,5], KERI L. DENAY[6], ALESSANDRA FERRI[1], MARTIN J. GIBALA[7], SAMUEL HEADLEY[8], ANDREW M. JONES[9], MARY JUNG[10], MATTHEW J.-C. LEE[1,11], TRINE MOHOLDT[12,13], ROBERT U. NEWTON[14,15], SOPHIA NIMPHIUS[16], LINDA S. PESCATELLO[17], NICHOLAS J. SANER[1], and CHRIS TZARIMAS[18]

[1]The Exercise Prescription Lab, The Institute for Health and Sport (IHES), Victoria University, Melbourne, Victoria, AUSTRALIA; [2]School of Allied Health, Sport and Social Work, Griffith University, Gold Coast campus, QLD, AUSTRALIA; [3]The Bone Clinic, Brisbane, Queensland, AUSTRALIA; [4]Centre for Health Research, University of Southern Queensland, AUSTRALIA; [5]Faculty of Sport & Health Sciences, University of Jyväskylä, FINLAND; [6]Department of Family Medicine, University of Michigan Medical School, Ann Arbor, MI; [7]Department of Kinesiology, McMaster University, Hamilton, ON, CANADA; [8]Department of Exercise Science, Springfield College, Springfield, MA; [9]Department of Public Health and Sport Science, University of Exeter Medical School, Exeter, UNITED KINGDOM; [10]School of Health and Exercise Sciences; University of British Columbia, Okanagan Campus, Kelowna, British Columbia, CANADA; [11]Institute for Physical Activity and Nutrition (IPAN), School of Exercise and Nutrition Sciences, Deakin University, Geelong, Victoria, Australia; [12]Department of Circulation and Medical Imaging, Norwegian University of Science and Technology, Trondheim, NORWAY; [13]Department of Obstetrics and Gynecology, St. Olav's Hospital, Trondheim, NORWAY; [14]Exercise Medicine Research Institute, Edith Cowan University, Joondalup, AUSTRALIA; [15]School of Human Movement and Nutrition Sciences, The University of Queensland, St Lucia, AUSTRALIA; [16]School of Medical and Health Sciences, Edith Cowan University, Joondalup, AUSTRALIA; [17]Department of Kinesiology, University of Connecticut, Storrs, CT; and [18]Central & Eastern Sydney Primary Health Network (CESPHN), New South Wales, AUSTRALIA

ABSTRACT

BISHOP, D. J., B. BECK, S. J. H. BIDDLE, K. L. DENAY, A. FERRI, M. J. GIBALA, S. HEADLEY, A.M. JONES, M. JUNG, M. J.-C. LEE, T. MOHOLDT, R. U. NEWTON, S. NIMPHIUS, L. S. PESCATELLO, N. J. SANER, and C. TZARIMAS. Physical Activity and Exercise Intensity Terminology: A Joint American College of Sports Medicine (ACSM) Expert Statement and Exercise and Sport Science Australia (ESSA) Consensus Statement. *Med. Sci. Sports Exerc.*, Vol. 57, No. 11, pp. 2599–2613, 2025. The evidence supporting the many beneficial effects of physical activity, including exercise, is overwhelming. This has led to numerous publications, statements, and position stands providing evidence-based recommendations to realize the performance-enhancing and therapeutic benefits of exercise. However, one factor hampering research and limiting the adoption of these recommendations is the inconsistent use of terminology associated with different exercise intensities. The goal of this international group of researchers and practitioners, therefore, was to propose standardized physical activity and exercise intensity terminology that has utility across all ages, sexes, genders, physical abilities, conditions, applications, and activities. After much discussion, we propose a standard terminology for physical activity, exercise, and sport and human performance comprising five exercise intensities: very low, low, moderate, high, and very high. We also propose five different descriptors for the perception of effort that align with the five intensities we have suggested: very easy, easy, somewhat hard, hard, and very hard. To enable consistent use of these descriptors with both cardiorespiratory and resistance exercise, we suggest not using descriptors such as light, heavy, weak, or strong (which might be perceived as only being applicable to describing load). We appreciate that some fields have long-established terminology and may be reluctant to change. Nonetheless, at a minimum, the terminology proposed here allows for more clarity when comparing the different exercise intensity

Address for correspondence: David J. Bishop, 70/104 Ballarat Rd, Footscray, VIC 3011, Australia; The Exercise Prescription Lab, Institute for Health and Sport (IHES), Victoria University, Melbourne, Victoria, Australia; E-mail: david.bishop@vu.edu.au.

0195-9131/25/5711-2599/0
MEDICINE & SCIENCE IN SPORTS & EXERCISE®

DOI: 10.1249/MSS.0000000000003795

descriptors currently used by different fields. Finally, we hope this will be an important "first step" in harmonizing the descriptions of exercise intensity across the fields of physical activity for public health, exercise science, and sport science. **Key Words:** CARDIORESPIRATORY EXERCISE, EXERCISE IS MEDICINE, HEALTH, PRESCRIPTION, PUBLIC HEALTH, RESISTANCE TRAINING, SPORT

Why Is Exercise Prescription[1] Important?

Evidence supporting the many beneficial effects of physical activity, including exercise, is overwhelming (1,2). Regular exercise improves exercise capacity, exercise tolerance, performance, and health (3,4). The magnitude of the fitness, performance, and health benefits associated with regular exercise is influenced by factors such as the frequency, type, volume, and intensity of the exercise performed (5).

The principles of training commonly implemented for enhancing human performance are increasingly being applied to the use of exercise to maintain or improve health, to attenuate or reverse various chronic diseases and health conditions (6–12), and as an adjunct therapy to improve the outcomes of surgery, radiation, and drug treatment (13,14). Given these many benefits, the Academy of Royal Medical Colleges has labeled exercise a potential "Wonder Drug" (15). Moreover, and analogous to drugs or pharmaceutical therapies, the prescription is an important determinant of the subsequent health-related outcomes of exercise (2,16–18).

There is clearly a need for evidence-based exercise prescriptions to realize the performance-enhancing and therapeutic benefits of exercise (6). Exercise prescription commonly refers to a specific plan of exercises or physical activities that are designed in a systematic and individualized manner for a specified purpose. To improve performance[2], exercise prescription requires an assessment of an individual's strengths and weaknesses and then adherence to a training program designed to optimize performance. In the context of health, exercise prescription involves considering and assessing priority health issues and designing an exercise program that specifically targets beneficial adaptations and minimizes any associated risks (12).

A Historical Perspective on Exercise Prescription

> *Lack of activity destroys the good condition of every human being, while movement and methodical physical exercise save it and preserve it.*—a modern interpretation of the writing of Plato (427–347 BCE)

Purposeful physical activity has been present in human societies throughout history, typically involving activities such as hunting, conflict, transport, and rituals or entertainment (e.g., dancing). Many of these physical activities evolved into sports, and, subsequently, the term exercise was conceived to describe a subclassification of physical activity conducted for the purpose of developing the specific skills and fitness characteristics needed for these activities. From these beginnings, the science of training emerged and continues to evolve. Recently, however, some scientists have raised concerns about the absence of common terminology when prescribing exercise to improve physical performance (19,20).

The concept of *exercise as medicine* also has its roots in antiquity. Physicians from many different ancient cultures prescribed exercise to enhance health and treat multiple diseases (21). These prescriptions ranged from performing generic exercise daily, to specific exercises targeting diseases, to avoiding exercise of excessive intensity for "weakened patients" (21). The need for a more scientific approach to the prescription of exercise as medicine was recognized in the first American College of Sports Medicine (ACSM) Guidelines for Graded Exercise Testing and Exercise Prescription, published in 1975 (22). Since then, numerous publications, statements, and position stands have provided physical activity and exercise recommendations to enhance health (17,23,24). However, as noted in a joint position statement by Exercise and Sports Science Australia (ESSA) and Fitness Australia (25), one factor limiting the adoption of these recommendations is the inconsistent use of terminology associated with the prescription of exercise.

Definitions of Key Exercise Prescription Terminology and Concepts

In many guidelines, exercise is prescribed using the FITT (VP) principle (26):

F: Frequency (how often)

Box 1: Key Terms related to physical activity and exercise prescription.

Physical activity: any bodily movement produced by the contraction of skeletal muscles that increases energy expenditure above the basal level (27). This includes Incidental Physical Activity (or activities of daily living, such as cooking and cleaning) and Intentional Physical Activity (e.g., non-structured physical activity, such as walking the dog).

Exercise: a subcategory of physical activity that is planned and structured, in which muscle contractions are performed with the explicit intent of ultimately improving or maintaining one or more components of physical fitness (e.g., aerobic capacity, muscle strength, power, and endurance, body composition, balance, coordination, or flexibility) and/or achieving a specific health benefit (28).

Sport: another subcategory of physical activity; it involves gross motor movement that is rule governed, structured, and competitive (29).

Cardiorespiratory fitness: cardiorespiratory fitness reflects the integrated ability of the circulatory and respiratory systems to supply oxygen to skeletal muscle mitochondria for the energy production needed during physical activity (30). Cardiorespiratory fitness is often expressed as maximal oxygen consumption ($\dot{V}O_{2max}$) or is estimated from

[1]For simplicity, we use the terms prescription and programming interchangeably in this article, even though some strength and conditioning professionals may prefer the term programming.

[2]Performance may be sporting (for recreational to elite athletes) or occupational (e.g., firefighters, military personnel, etc).

the maximum work rate achieved on an ergometer or from non-exercise algorithms.

Cardiorespiratory exercise: exercise that requires the circulatory and respiratory systems to work together to support the metabolism of skeletal muscles and other organs to enable sustained exercise. It is preferred over terms such as aerobic exercise (which, at best, only describes the predominant energy system used) or endurance exercise (which describes only one of the potential types of performance improvements with this type of exercise). It includes activities in which the body's large muscles move in a rhythmic manner for a sustained period of time, such as walking, running, swimming and cycling (23).

Metabolic threshold: a term used to describe an exercise intensity that results in an apparent change in metabolism (usually reflected by changes in oxygen uptake, carbon dioxide production, ventilation, or metabolites in the muscle and blood) (31). The first detectable change in metabolism is often termed the first metabolic threshold, whereas the second detectable change in metabolism is often termed the second metabolic threshold (see also Fig. 4).

Body Composition: the relative proportions of the total body mass divided into the two components of fat mass and fat-free mass (32–36).

Muscle strength: the ability of muscle to exert force during a specified task (37).

Muscle power: the ability of muscle to exert force at a given velocity of movement (i.e., the product of the muscle force vector and action velocity of the muscle) or the rate of doing work (work done divided by time) (38–39).

Muscle endurance: the ability of muscle to continue to exert force (40).

Muscle fitness: a global term that includes muscle strength, muscle power, and local muscle endurance (41).

Resistance exercise: a form of exercise that requires skeletal muscles to exert force to push or pull against resistance with sufficient effort such that the number of repetitions or duration of contractions is limited due to neuromuscular fatigue. The resistance may include body weight, elastic bands, free weights, and weight or other mechanical machines, among others (42).

Flexibility: the ability to move a joint through its maximal unrestricted range of motion without pain (43–47).

Perception of effort: "also known as perceived exertion or sense of effort, has been proposed to integrate feelings of effort, strain, and/or fatigue from the peripheral muscles and joints, the cardiopulmonary system, and the central nervous system to provide a cognitive feeling of effort associated with physical activity" (48,49).

I: Intensity (how hard)
T: Time (duration of individual exercise sessions)
T: Type (what kind)
V: Volume (total amount of exercise)
P: Progression (exercise advancement).

Other key terms related to the prescription of exercise can be found in Box 1.

Intensity

Intensity (ɪnˈtɛnsɪtɪ)—noun: degree, extent, or relative magnitude

Although all of the FITT(VP) components are important for exercise prescription, this statement will focus on intensity given its importance and the ambiguity surrounding the associated terminology. Exercise intensity can be expressed in absolute (i.e., a given work rate or resistance) or relative (e.g., percentage of one's maximum capacity) terms and is an important determinant of changes in health and fitness (24,50), as well as the risk of adverse events during exercise in some individuals (51,52) (Fig. 1). Furthermore, the overload principle of training states that exercise below a minimum intensity will not challenge the body sufficiently to alter structure, physiology, or health (24). Despite the importance of intensity, the independent evolution of physical activity for public health, exercise science, and sport science has led to the adoption of many different, and often inconsistent, terms to define exercise intensity. These inconsistencies create uncertainty for scientists and practitioners, as well as the public, and hamper the optimal prescription of exercise to improve health, physical fitness, and human performance.

Aims

There is no greater impediment to the advancement of knowledge than the ambiguity of words (Thomas Reid, 1852. Essays on the Intellectual Powers of Man)

The use of standard terminology when describing the intensity of physical activity or exercise is important for characterizing physical activity trends accurately, collecting valid and reliable data for research purposes, informing policy (e.g., physical activity guidelines), and establishing the optimal prescription of exercise to improve health, fitness, and performance (9,53). For the *Exercise is Medicine®* initiative to realize its therapeutic potential, it is important that standard descriptors are used by all researchers and practitioners when assessing or targeting responses to different exercise intensities (54). Ideally, the same terms should be used by physical activity, exercise science, and sport science researchers, professional associations, policymakers, and practitioners providing recommendations to the public and athletes. This is also important as the results of individual studies cannot be effectively harnessed (e.g., when performing meta-analyses) unless there is uniform terminology and common characteristics of the different exercise intensities employed. Thus, an important aspect of this expert statement is to compare and map the different exercise intensity terms used in different fields, and to highlight where there are inconsistencies and potential for confusion. This expert statement also builds on previous literature and proposes a new standardized framework for describing and prescribing exercise intensity. Our aspiration is that the adoption of standard terminology when prescribing and monitoring exercise intensity will lead to improved health, fitness, and performance outcomes.

Caveats

Our goal is to propose standardized physical activity and exercise intensity terminology that has utility across all ages,

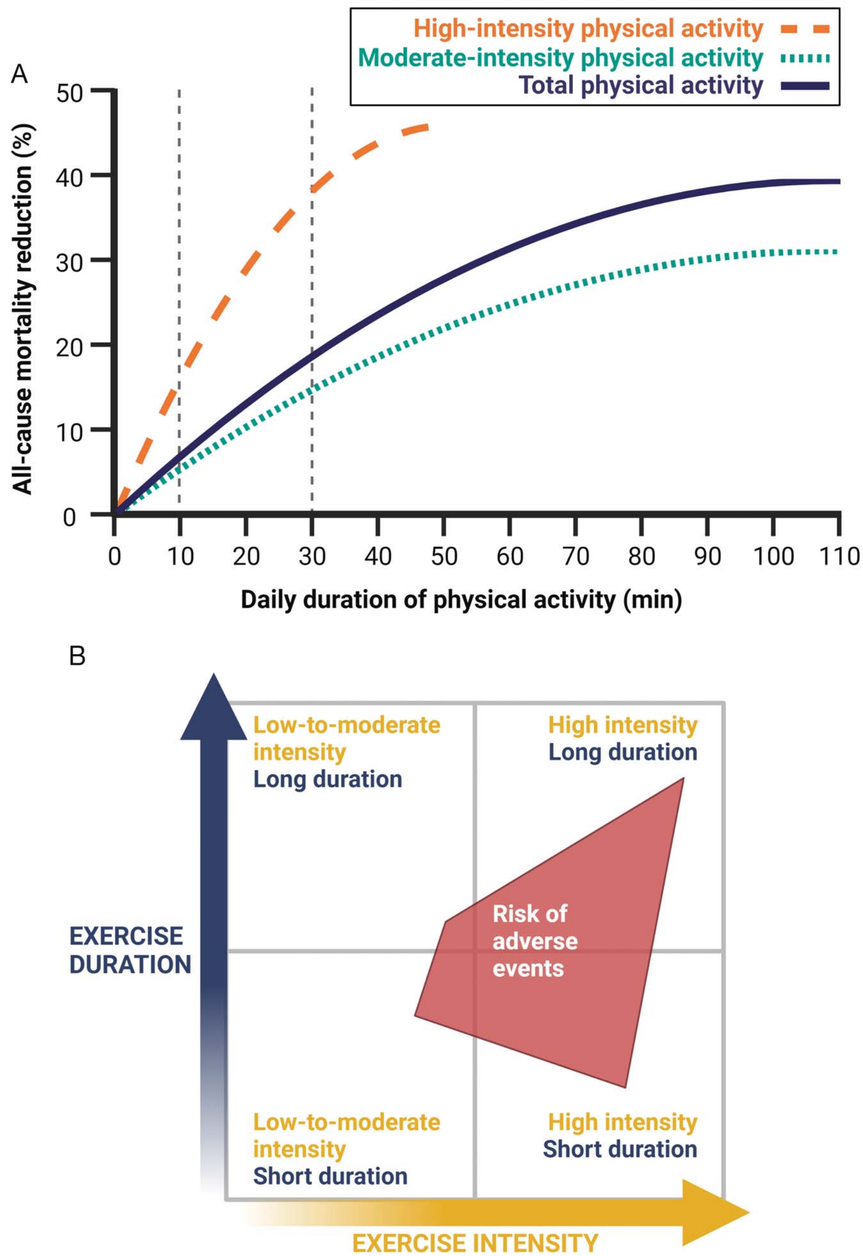

FIGURE 1—Exercise intensity is considered an important determinant of (a) all-cause mortality reduction with physical activity and (b) the risk of adverse events during exercise. Based on Wen et al. (50) and Lie et al. (52).

sexes, genders, physical abilities, conditions, applications, and activities. Although this is the focus of this statement, it does not diminish the importance of other important exercise prescription components defined by the FITT(VP) principle that will not be addressed in this statement (i.e., frequency, type, time, volume, and progression). It is also beyond the scope of this brief statement to address the many external factors (e.g., nutrition, sleep, environment, medications, etc.) that can affect physiological and perceptional responses to exercise.

Overview of Current Terminology Used to Describe the Intensity of Cardiorespiratory Activities

Physical activity. Despite its ubiquitous use (a search for the term "exercise intensity" in Google Scholar returns more than 400,000 hits; accessed on July 30, 2024), there are inconsistencies in the terminology used by researchers, practitioners, and leading agencies to categorize the intensity of physical activity (Fig. 2). For example, an international consensus project on physical activity and sedentary behavior terminology (55), the World Health Organization (23), and the *Physical Activity Guidelines for Americans* (56) use the terms light, moderate, and vigorous intensity. The ACSM's *Guidelines for Exercise Testing and Prescription* also recommend the descriptors light, moderate, and vigorous but add very light and near-maximal to maximal as their lowest and highest activity intensities, respectively (24). A position statement by ESSA also uses the categories light, moderate, and vigorous, but describes their lowest and highest exercise intensities as sedentary and high (25). Similar

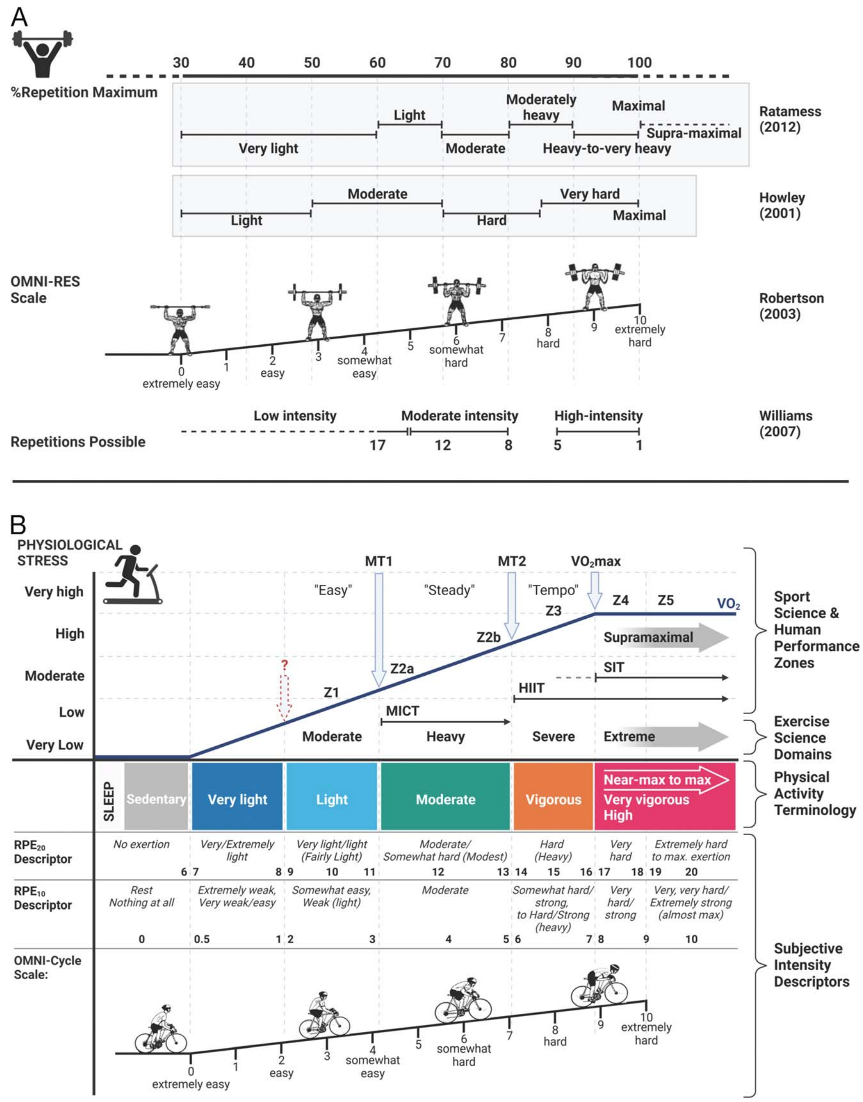

FIGURE 2—Inconsistencies in some of the many terms used by researchers, practitioners, and leading agencies to categorize (in)activity and exercise intensity for both (a) resistance exercise and (b) cardiorespiratory exercise. This inconsistency also applies to the various RPE numerical anchors that have been associated with the different exercise intensities. Note that there are two RPE scales in common use—the original Borg Scale ranging from 6 to 20 (RPE_{20}) and the Category Ratio Scale ranging from 0 to 10 (RPE_{10}). HIIT, high-intensity interval training; MICT, moderate-intensity continuous training; MT, metabolic threshold; SIT, sprint interval training; Z, Zone.

to the initial ESSA position statement (25), the UK Chief Medical Officers' Physical Activity Guidelines describe physical activity as light, moderate, and vigorous, but describe their highest intensity as very vigorous (57). Thus, despite some concordance of physical activity intensity terminology between different sources, there are also clear differences that can make guidelines and recommendations confusing for practitioners and the public.

Exercise. Based on the characteristic bioenergetic response to exercise, four intensity domains have been identified for cardiorespiratory exercise; these are moderate (intensities below the first metabolic threshold), heavy (intensities between the first and second metabolic threshold), severe (intensities above the second metabolic threshold that can be sustained until the maximal rate of oxygen consumption ($\dot{V}O_{2max}$) is attained), and extreme (intensities resulting in task failure before $\dot{V}O_{2max}$ is attained) (58). In each domain, the time course of the kinetics for the oxygen uptake ($\dot{V}O_2$) response differs (58), and there are distinct muscle metabolic and blood acid–base responses (31) and principal causes of the inability to continue exercising (i.e., exercise intolerance) (59).

These terms are rarely used within the clinical setting, where exercise intensity is more often defined using terms that parallel those used in Physical Activity Guidelines (as described previously). In this way, it is possible to assess if an individual is meeting current guidelines and then help them meet or continue to meet these recommendations. However, similar terminology is not always used for both physical activity and exercise prescription (see Fig. 2). For example, an ESSA position statement on exercise in cancer management refers to low-, moderate-, or high-intensity exercise (12), even though an earlier position statement on exercise terminology from the same organization recommends the terms light, moderate, and vigorous for both physical activity and exercise intensity (25).

Sport and human performance. The intensity domains described previously, which are based on physiological responses to exercise (e.g., dynamics of pulmonary $\dot{V}O_2$, blood lactate concentration, muscle phosphocreatine concentration), have analogues in the prescription of training intensities for improving human performance (Fig. 2). While these may be numerical (e.g., zones 1, 2, and 3, although noting that many different schemas exist), they can also be descriptive. This leads to exercise below the first metabolic threshold being commonly described as easy (60) or low-intensity training (61). Exercise performed at an intensity greater than the first metabolic threshold but less than the second metabolic threshold is often referred to as steady (60); this training zone also includes moderate-intensity training (61) or moderate-intensity continuous training (62). Exercise greater than the second metabolic threshold but less than $\dot{V}O_{2max}$ is commonly described as tempo; this training zone also includes high-intensity interval training (60). The final training zones(s) is characterized by efforts performed at intensities equal to or greater than the work rate associated with the attainment of $\dot{V}O_{2max}$ during a graded exercise test (GXT) and includes sprint interval training (63). Here again, the potential for confusion is obvious as high-intensity interval training sits in the severe and extreme intensity domains and corresponds to vigorous-intensity physical activity (and requires hard/strong to extremely hard/strong exertion).

Overview of Current Terminology Used to Describe the Intensity of Resistance Exercise

Physical activity. There is clinical and epidemiological evidence that performing resistance exercise is independently associated with multiple health outcomes (64). At present, however, the surveillance and prescription of resistance exercise in the context of physical activity is based predominantly on frequency (i.e., include “muscle-strengthening”[3] activities as part of daily physical activity on at least 2 d each week; [9]), with no consideration of intensity—even though this is likely to affect health outcomes (65). Of note, the UK Chief Medical Officers’ Physical Activity Guidelines only list resistance exercises (weight exercises, push-ups) in their highest very vigorous intensity category (57).

Exercise, sport, and human performance. When making resistance training recommendations for the apparently healthy, the clinical management of patients, and to improve performance, resistance training intensity is often used interchangeably with load (i.e., the amount of weight lifted) or the number of repetitions possible with a specific load (Fig. 2). For example, a recent international consensus statement uses the terms light, moderate, and high to describe resistance training intensities associated with different percentages of an individual’s one-repetition maximum (1RM) (66). The ACSM’s Foundations of Strength Training and Conditioning book also classifies intensity with respect to percentages of an individual’s 1RM (e.g., resistance training intensities range from very light to very heavy and supramaximal based on percentages of an individual’s 1RM) (41). Based on 1RM percentages, a resistance training intensity classification analogous to that commonly used for prescribing cardiorespiratory exercise intensity has also been suggested (i.e., very light, light, moderate, hard, very hard, maximal) (67). Taking a different approach, a scientific statement from the American Heart Association classifies resistance training intensity as low, moderate, or high based on the maximum number of repetitions that can be completed with a given load (i.e., repetitions maximum, or RM) (68). However, another approach is to use perceptual scales to define resistance training intensities that range from extremely easy to extremely hard (69). There is currently no clear consensus on the best terms to describe the intensity of resistance exercise.

[3]We do not recommend the term “muscle-strengthening,” as this neglects the many other benefits of performing resistance exercise (e.g., muscle hypertrophy, increasing bone density, endocrine and immune benefits, etc).

A Proposal for Standard Terminology When Describing Exercise Intensity

Although an international consensus project primarily focused on sedentary behavior terminology settled on only three intensities of physical activity (55), recommendations from national exercise and public health associations typically expand this to four or five intensities (24,25,57). This aligns with the four intensity domains derived from the bioenergetic or neuromuscular underpinnings of exercise intensity, even though there is no intensity below Moderate within this bioenergetic framework (58). Thus, taking current practices into consideration, we propose a standard terminology for physical activity, exercise, and sport and human performance comprising five exercise intensities: Very Low, Low, Moderate, High, and Very High[4] (Fig. 3). We appreciate that some fields have long-established terminology and may be reluctant to change. Nonetheless, at a minimum, the terminology proposed here allows for more clarity when comparing the different exercise intensity descriptors currently used by different fields.

Although the term light is well established when describing physical activity for health (55), we argue that there is potential for confusion when terms such as light (and also heavy) are applied to resistance exercises. Although the term vigorous is also well established in the physical activity field (23,55), we suggest that High is more appropriate linguistically as an intensity that is above Moderate-intensity exercise. The use of High intensity also better aligns with the well-established view that high-intensity interval training is performed at this intensity (70). Finally, we propose avoiding the term “supramaximal” to describe exercise intensity. In our view, this term is problematic as the Oxford dictionary defines maximal as “the greatest intensity possible,” and *supra* is derived from the Latin for “above, over, beyond”; thus, it seems misplaced to describe an exercise intensity as “beyond the greatest intensity possible.”

[4]Throughout this manuscript, we have capitalized our newly proposed intensity descriptors to aid the reader.

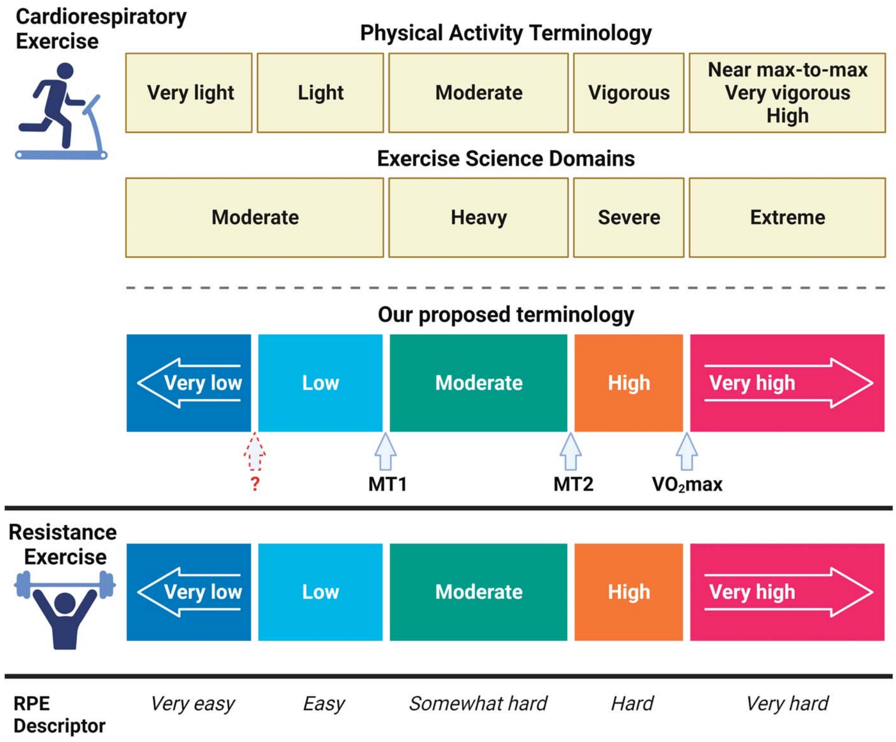

FIGURE 3—Proposal for standard terminology to describe exercise intensity for physical activity, exercise, and sport and human performance. MT, metabolic threshold.

Based on the pioneering work of Gunnar Borg (71), we propose five different descriptors for the perception of effort that align with the five intensities we have suggested: very easy, easy, somewhat hard, hard, and very hard. Again, to enable consistent use of these descriptors with both cardiorespiratory and resistance exercise, we suggest not using descriptors such as light, heavy, weak, or strong (which might be perceived as only being applicable to describing load).

How to Determine and Monitor the Different Exercise Intensities

Current approaches to prescribing cardiorespiratory exercise intensity. There is currently no consensus regarding which of the many commonly used methods to establish different exercise intensities for different populations is best (see Table 1). Some of the traditional methods for determining exercise intensity include:

a) threshold-based approaches,
b) percentages of different anchor measurements,
c) fixed values, and
d) perceptual measures.

Metabolic thresholds. For nearly 50 y, the direct measurement of metabolic thresholds has been proposed as the preferred method to define exercise training categories that produce similar physiological stresses in individuals with different exercise capacities (72). The advantages of this approach include a strong theoretical rationale and the fact that many of the thresholds are not influenced by the motivation or effort of individuals (an important consideration for clinical populations) (73). Disadvantages include the need for expensive equipment and time-consuming exercise tests, which may also involve all-out efforts (to determine critical power/critical speed) and/or invasive blood sampling (to determine the lactate thresholds (LT) and the maximal lactate steady state (MLSS)), and the need for expertise to analyze and interpret the data. Another limitation of this approach is that methods have only been proposed to demarcate the lower and upper bounds of the Moderate-intensity exercise category (according to our proposed terminology in Fig. 3). A final limitation is that many methods exist to determine the metabolic thresholds, as highlighted by others (62,73–75).

Notwithstanding disagreements regarding nomenclature, definitions, and the most appropriate protocols and analysis methods (62,73–75), there is a general consensus that the first metabolic threshold can be approximated by the LT (the first increase in blood lactate concentration above baseline), the gas exchange threshold (a nonlinear increase in carbon dioxide output ($\dot{V}CO_2$) plotted as a function of $\dot{V}O_2$), or the ventilatory threshold (a nonlinear increase in minute ventilation) (Fig. 4). There is less consensus regarding the second metabolic threshold, with most of the debate concerning whether the MLSS or critical power/speed should be considered the "gold standard" (76–79). However, if measured accurately, it appears that both the MLSS and critical power/speed occur at a similar metabolic rate (80,81). Furthermore, exercise prescribed at intensities above and below the confidence interval ('band of uncertainty') for either estimate should lead to clear differences in metabolic

TABLE 1. Current descriptors and criteria used to estimate different physical activity/exercise intensities, based on the ESSA position statement (42), ACSM's *Guidelines for Exercise Testing and Prescription* (41), and Howley (66).

	Cardiorespiratory Exercise															Resistance Exercise
	% $\dot{V}O_{2max}$			%HRR			%HRmax			RPE_{20} (6–20)			METs			% 1RM
Intensity Descriptor	ESSA (2010)	ACSM (2020)	Howley (2001)[a]	ESSA (2010)	ACSM (2020)	Howley (2001)[a]	ESSA (2010)	ACSM (2020)	Howley (2001)[a]	ESSA (2010)	ACSM (2020)	Howley (2001)[a]	ESSA (2010)	ACSM (2020)	Howley (2001)[a]	Howley (2001)
Sedentary	<20			<20			<40			<8			<1.6			
Very light		<37	<28		<30	<20		<57	<50		<9	<10		<2.0	<2.8	<30
Light	20–40	37–45	28–45	20–40	30–39	20–39	40–55	57–63	50–63	8–10	9–11	10–11	1.6–3	2–2.9	2.8–4.5	30–49
Moderate	40–60	46–63	45–63	40–60	40–59	40–59	55–70	64–76	64–76	11–13	12–13	12–13	3–6	3–5.9	4.6–6.3	50–69
Hard			64–86			60–84			77–93			14–16			6.4–8.6	70–84
Very hard			≥87			≥85			≥94			17–19			≥8.7	≥85
Vigorous	60–85	64–90		60–85	60–89		70–90	77–95		14–16	14–17		6–9	6–8.7		
High	≥85			≥85			≥90			≥17			≥9.0			
Near-Max		≥91			≥90			≥86			≥18			≥8.8		
Maximal			100			100			100			20			10	100

[a]Suggested values assuming that $\dot{V}O_{2max}$ = 10 METs or 35 mL $O_2 \cdot kg^{-1} \cdot min^{-1}$ (66).

response (as reflected by $\dot{V}O_2$ kinetics, ventilation, lactate, and other metabolites) and improve the specificity of individual exercise prescriptions.

Various parameters determined from GXTs[5] have been proposed as indirect measures to demarcate the Low, Moderate, High, and Very High-intensity training zones (using our proposed definitions and illustrated in the upper panel of Fig. 4) (73). There is general consensus that some gas exchange and ventilatory parameters, such as the gas exchange threshold or ventilatory threshold, derived from a GXT (consisting of relatively short increments of ~1 min), can be used to approximate the first metabolic threshold (73) but that others (e.g., the respiratory compensation point) may overestimate the second metabolic threshold (77); the intensity associated with the $\dot{V}O_{2max}$ determined during this type of GXT can also be used to define the upper boundary of the high-intensity training zone. There is also a general consensus that some lactate parameters (e.g., the first LT) derived from a GXT (consisting of longer increments of ~3 to 5 min) can be used to approximate the first metabolic threshold (73). However, the use of lactate parameters derived from the same GXT to estimate the second metabolic threshold is complicated by the myriad of GXT protocols and methods used to calculate the second LT (62,75). Nonetheless, there is evidence that some of these lactate parameters can provide a good approximation of the second metabolic threshold (74). However, the intensity at the $\dot{V}O_{2peak}$[6] established from a GXT with longer increments can underestimate the work rate associated with the upper boundary of the high-intensity training zone by 20% to 30% (74).

Percentages of different anchor measurements. Despite their continued use in both research and exercise guidelines (see Table 1), it is clear that exercise intensity prescriptions based on fixed percentages of maximum values (e.g., $\dot{V}O_{2max}$ and maximum heart rate (HR_{max})) do not achieve category-specific metabolic responses in all individuals (72,82,83). For example, one study reported a 40-fold range for the increase of muscle lactate in different individuals following exercise at 70% of $\dot{V}O_{2max}$ (84). Nearly 50 y ago, another study reported that when exercising at 80% of HR_{max}, approximately half of the participants were above their first metabolic threshold and approximately half were below (72). Although other methods have been proposed to place individuals at a more similar intensity above resting metabolism (e.g., $\dot{V}O_2$ reserve ($\dot{V}O_2R$) = $\dot{V}O_{2max} - \dot{V}O_{2Rest}$ or HR reserve (HRR) = $HR_{max} - HR_{Rest}$), these methods similarly do not achieve comparable metabolic stress for all individuals (82). Thus, despite their common use, prescribing exercise intensity based on a fixed percentage of maximal anchors (e.g., %$\dot{V}O_{2max}$, %$\dot{V}O_2R$, %HR_{max}, or %HRR) will cause individuals to exercise in different training intensity categories and to experience large variations in metabolic stress and, presumably, the training stimulus.

Fixed values. It is widely understood that if individuals of different fitness levels exercise at the same absolute work rate, $\dot{V}O_2$, or HR, they may experience markedly different cardiovascular and metabolic stress (82). Consequently, these methods are not recommended, and are rarely used, for prescribing different exercise intensities. However, one method of exercise prescription based on absolute values that continues to be utilized, especially in physical activity and exercise medicine settings, is metabolic equivalents or METs (see Table 1 and Fig. 4). The MET of any physical activity for an individual is their energy expenditure (per kilogram of body mass) relative to the amount of energy used while sitting quietly (i.e., resting energy expenditure equals 1 MET or 3.5 mL $O_2 \cdot kg^{-1} \cdot min^{-1}$). The main criticism of this intensity classification system is that fixed MET values do not adequately consider individual differences (e.g., age, sex, gender, body mass, and fitness), which can lead to different physiological stresses and the misclassification of cardiorespiratory exercise intensity categories for different individuals (85). For example, it was reported that the upper limit of the low-intensity and moderate-intensity categories ranged between 2 and 13 METs and 3 and 18 METs, respectively,

[5]Graded exercise tests are designed to be increasingly more difficult as they progress; the increments (grades) typically range from ~1 to 5 min.

[6]The main difference between $\dot{V}O_{2peak}$ and $\dot{V}O_{2max}$ is that the $\dot{V}O_{2max}$ is the maximum rate of oxygen consumption during physical exertion, whereas the $\dot{V}O_{2peak}$ is the highest rate of oxygen consumption during a specific exercise task. The $\dot{V}O_{2peak}$ is often less than the $\dot{V}O_{2max}$, especially when a relatively small muscle mass is recruited during the task and/or when used in clinical settings.

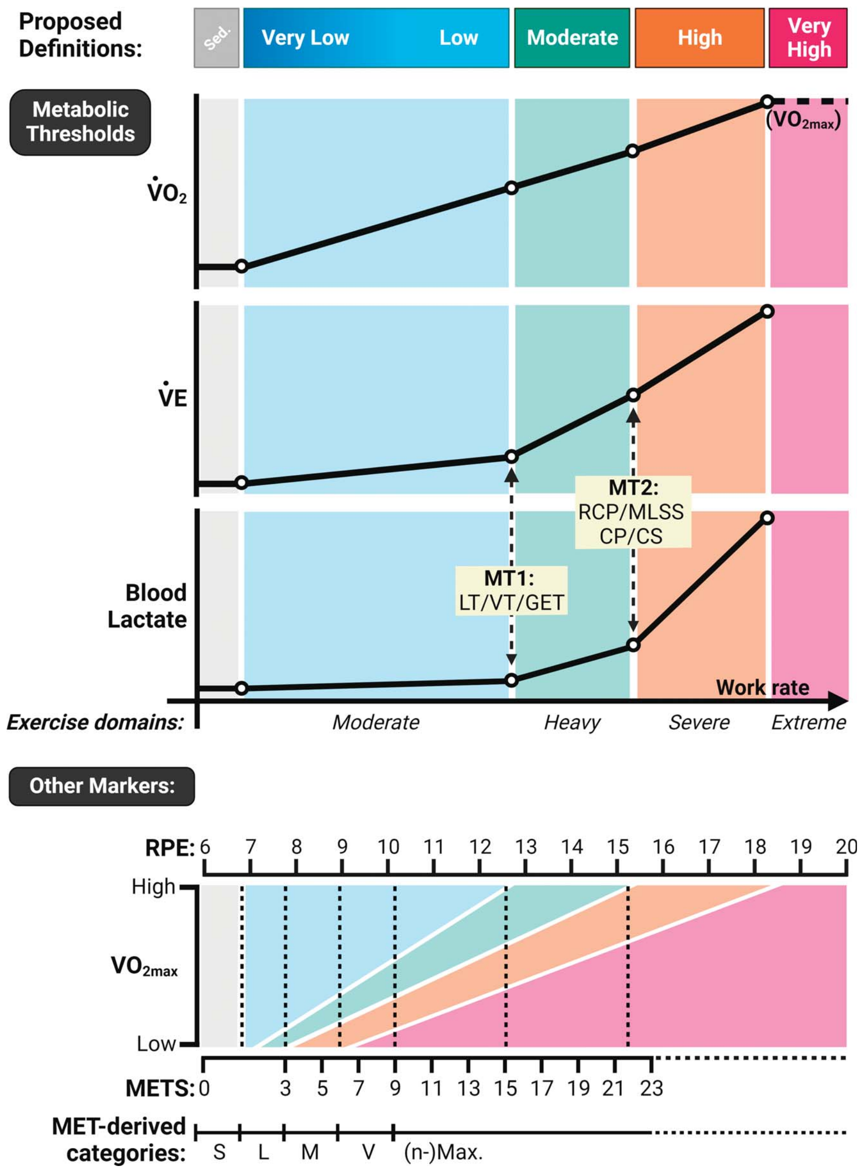

FIGURE 4—a, Common metabolic thresholds that have been considered, though not unequivocally, to partition the primary exercise intensity descriptors that we have proposed (see above and Fig. 3). CP/CS, critical power/speed; GET, gas exchange threshold; LT, lactate threshold; MT, metabolic threshold; RCP, respiratory compensation point; VT, ventilatory threshold. b, Schematic representation of how common markers, based on fixed ranges, are not appropriate to prescribe and monitor the exercise intensity of individuals with different cardiorespiratory fitness levels. L, low; M, moderate; (n-)Max., near maximal; S, sedentary; V, very high.

whereas the high-intensity categories included METs from 4 and above (85). Thus, prescribing cardiorespiratory exercise based on METs is not an adequate method to elicit category-specific metabolic and physiological stresses for different individuals.

Perceptual measures. Perceptual methods (e.g., rating of perceived exertion (RPE), OMNI scale[7], Talk Test) have also been used and recommended to prescribe and monitor both cardiorespiratory (86) and resistance exercise intensity (69). The most well known of these methods is RPE, which has been proposed to integrate feelings of effort, strain, and/or fatigue from the peripheral muscles and joints, the cardiopulmonary system, and the central nervous system (48). Some researchers have concluded, based on mean values, that RPE can be a valid tool for prescribing different exercise intensities (87), but most studies have reported a large range and overlap for individual RPE values at the various metabolic thresholds (see bottom panel of Fig. 4). Typical RPE values for individuals (using the original 6–20 scale) can range from ~7 to 14 for the first metabolic threshold and ~9 to 17 for the second metabolic threshold (87–89). Similar ranges have been reported for the OMNI scale of perceived exertion—a 0 to 10 category rating scale that consists of both verbal descriptors and mode-

[7]OMNI is a contraction of the word *omnibus* and is used to indicate an RPE scale having broadly generalizable properties.

specific images of exertion (90–92). Although this suggests that it is not ideal to prescribe exercise intensity based on fixed RPE values (regardless of the scale used), it has been noted that RPE can be a useful auxiliary method to help monitor cardiorespiratory and resistance exercise prescriptions (24,25). This is best done if individuals are familiarized with the use of perceptual scales, and the RPE values corresponding to the different training intensities for each individual have been previously established via exercise tests.

Another perceptual tool proposed for the prescription and monitoring of exercise intensity is the "Talk Test" (93). The rationale is that changes in ventilation near the metabolic thresholds will affect speech production (94), and if comfortable speech is possible, most people who do not exercise regularly are likely to be exercising in the low-intensity training category (i.e., below the first metabolic threshold) (95). However, it has also been reported that the ability to talk comfortably can end before the first metabolic threshold in inactive participants (96) and patients enrolled in cardiac rehabilitation programs (97), but can continue well into the moderate-intensity training category for well-trained athletes (96). There is also evidence that many people will equivocate about their ability to speak comfortably when exercising in the moderate-intensity training category (93), but this can also occur in the low- or high-intensity training categories for some people (97). Although an obvious advantage of the Talk Test is that it removes the need for preliminary exercise tests to approximate different training intensity categories, there is little evidence that it is an accurate method to elicit physiological stresses consistent with different training intensities in most individuals. If used conservatively, it may be used in the absence of laboratory-based measures to try and limit cardiorespiratory exercise to below the High-intensity training category.

Current approaches to prescribing resistance exercise intensity. As with cardiorespiratory exercise, there is currently no consensus regarding how best to establish different resistance training intensities for different populations. The predominant recommendation is to prescribe resistance training intensity based solely on the load or force to be overcome (this is usually expressed as a percentage of maximal strength or the 1RM for each exercise). This conflation of load (how heavy) and intensity (how hard) appears to have originated from an article stating that the intensity of resistance training exercise can be estimated as a percentage of the 1RM (or any other RM resistance for the exercise) (42). It was subsequently suggested that the counterpart to $\dot{V}O_{2max}$ in resistance training is the 1RM, and that percentages of 1RM could form the basis of a resistance training intensity classification analogous to those commonly used for prescribing cardiorespiratory exercise intensity (67).

Concerns have been raised about resistance training intensity categories based on percent 1RM (98). The first is that intensity categories based only on load are not applicable to resistance training activities that do not involve free weights or weight machines (e.g., the use of body weight or elastic bands). The second is that the intensity of resistance training is determined not only by load[8] but also by the progression toward neuromuscular failure (sometimes expressed as repetitions in reserve (RIR)[9]) (see Fig. 5). For example, a load of 50% 1RM may be Low to Moderate intensity over the initial repetitions, but the intensity becomes Very High when the number of repetitions continues to neuromuscular failure. It has also been reported that there is a large variability in the number of repetitions that can be performed at the same percent 1RM (e.g., one study reported that well-trained lifters could perform 6–26 repetitions at 70% of their individual 1RM [99]). This has led to some researchers suggesting that RIR, an estimation of the proximity to neuromuscular failure, could be an alternative method of prescribing resistance exercise intensity (100).

Another method of prescribing resistance training intensity is based on the individual's repetition maximum for a given exercise (the exercise is performed with a weight that would allow a given number of repetitions to be completed and no more; e.g., 6-RM refers to a weight that can only be lifted 6 times with good form) (see Fig. 2a) (68). However, intensity categories based only on the number of repetitions that can be completed with a given load before failure also do not consider that resistance training intensity is determined by the load, the actual number of repetitions completed, and other exercise characteristics that will influence the progression toward neuromuscular failure (e.g., type of contraction, inter-set recovery[10], speed of movement, and eccentric/concentric timing[11]). Furthermore, it could be argued that any resistance training load will be of a High to Very High intensity at the point of neuromuscular failure. Another method to monitor how hard it is to perform resistance exercise (i.e., the resistance-training intensity) is the OMNI-RES scale of perceived exertion—a 0 to 10 category rating scale that consists of images depicting a weight lifter displaying different degrees of exertion alongside corresponding verbal descriptors (extremely easy to extremely hard) (69). More research is required to investigate the reliability and validity of this approach for prescribing resistance exercise intensity.

Putting It All Together: A Proposal for a Standard Approach When Describing and Prescribing Exercise Intensity

We have proposed more empirically derived, standard terminology for physical activity, exercise, and sport and human performance, applicable to both cardiorespiratory and resistance exercise, that consists of five exercise intensities (Very Low, Low, Moderate, High, and Very High) and five descriptors for the corresponding perception of effort (very easy, easy, somewhat hard, hard, and very hard) (Table 2). We acknowledge that there is no accepted marker to demarcate the Very Low and Low exercise intensities, but, after much discussion,

[8]Force produced by the activated muscle.
[9]Number of additional repetitions that can be completed before neuromuscular failure.
[10]Time between consecutive sets of exercise.
[11]Duration and ratio of eccentric and concentric phases of each repetition.

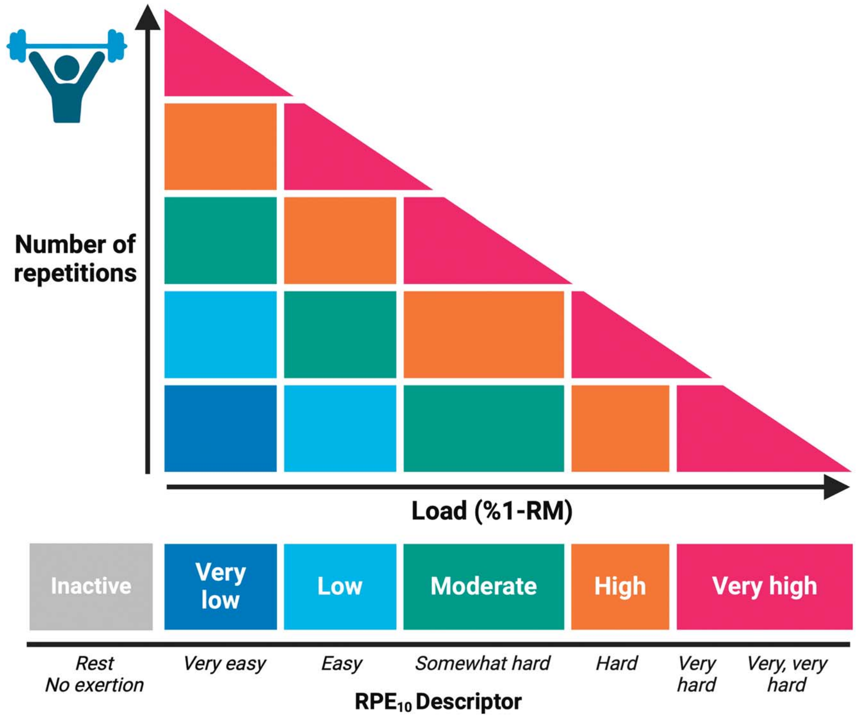

FIGURE 5—A schematic highlighting that resistance training intensity is determined by both load and the number of repetitions performed, which together will determine proximity to neuromuscular failure.

we have proposed five intensity categories to remain consistent with the number of intensity categories currently recommended by both ESSA and the ACSM (24,25). Given the evidence that the greatest improvements in health occur when going from being inactive to active (1), it was also deemed important to maintain a Very Low Intensity category. Further research is warranted to investigate if it is possible to discover a physiological/metabolic marker to distinguish between Very Low and Low intensity exercise.

It was also challenging to recommend appropriate methods to determine and monitor the other four proposed exercise intensity categories (i.e., Low, Moderate, High, and Very High) for cardiorespiratory exercise. However, based on the published evidence, we argue that the direct measurement of metabolic thresholds and the work rate associated with the attainment of $\dot{V}O_{2max}$ during a GXT (W_{max}) is the best and preferred method (where possible) to define exercise intensity categories that will produce similar physiological stresses in individuals with different exercise capacities (especially in research settings). We acknowledge that these laboratory-based assessments are not applicable to most people and are not feasible at a population level. However, despite their use in most current exercise guidelines, the published evidence is clear that current markers (e.g., $\%\dot{V}O_{2max}$, $\%HR_{max}$, %HRR, and METs) do not achieve category-specific cardiovascular and metabolic responses in all (or even most) individuals. Further research is warranted to determine if the accuracy of these markers can be improved, especially if they are based on the direct measurements of metabolic thresholds that we have suggested in this expert statement.

With caution, we recommend RPE as an adjunct method for prescribing and monitoring exercise intensity in those for whom laboratory-based assessments are not appropriate. We note, however, that further research is required to improve the accuracy of RPE ranges for individuals of different ages, sexes, genders, fitness levels, and health status. Further research is also needed to establish RPE ranges to demarcate the different exercise intensities we have proposed (when determined using direct methods, such as metabolic thresholds and W_{max}). We also note that research is required to better align the different RPE scales. For example, somewhat hard (or moderate) is 13 on the original 6 to 20 scale (RPE_{20}), but 3 on the RPE_{10} scale (also termed the 10-point Category Ratio) even though mathematically it would align more closely to 5 (which is used in the latest World Health Organization physical activity guidelines; [23]). If used conservatively, the Talk Test may be applied in the absence of laboratory-based measures to try and limit cardiorespiratory exercise to below the high-intensity training category.

TABLE 2. Proposed classifications and criteria used to estimate inactivity and physical activity/exercise intensity for different training categories.

	Cardiorespiratory Exercise	Resistance Exercise	Cardiorespiratory and Resistance Exercise	
Category	Physiological Reference	Reps in Reserve (RIR)	RPE_{10}	RPE_{20}
Inactive	Inactive	Inactive	0	6
Very low	No current measure	>8	<2	≤9
Low	<MT1	7–8	2–3	10–11
Moderate	>MT1 but <MT2	4–6	4–5	12–14
High	>MT2 but <W_{max}	2–3	6–7	15–16
Very high	>W_{max}	<2	8–10	≥17

MT1, the first metabolic threshold; MT2, the second metabolic threshold.

For resistance training, we do not recommend prescribing exercise intensity based on %1RM (i.e., a measure of load). Instead, we recommend using RIR (an estimation of how many more repetitions can be completed before neuromuscular failure) as a better measure of "how hard" the exercise feels. Although further research is required to better establish the validity and reliability of the RIR method to prescribe resistance training intensity, there is research that supports a linear relationship between proximity to neuromuscular failure and neuromuscular fatigue (101) and that the RIR method can be a reliable tool for resistance training prescription (100). As with the %1RM and RM methods, there is evidence that the RIR method is more reliable with experienced lifters (102). There may be value in using RIR in conjunction with other methods (e.g., the %1RM and RM methods) when trying to estimate starting loads for resistance training in populations with limited resistance training experience. We again recommend RPE as an adjunct method for prescribing and monitoring resistance-training exercise intensity. When these two measures do not agree, it is prudent, especially in clinical populations, to select the highest category as the defining intensity (consistent with hypertension guidelines).

CONCLUSIONS

In conclusion, exercise intensity is an important determinant of the fitness, performance, and health benefits of regular exercise. However, we have argued that the absence of consistent terms to define exercise intensity creates uncertainty for scientists and practitioners, as well as the public, and is hampering the optimal prescription of exercise to improve health, physical fitness, and human performance. This expert statement builds on previous literature and proposes a standard framework for describing, prescribing, and monitoring exercise intensity across different disciplines and fields. We have proposed a standard terminology for physical activity, exercise, and sport and human performance, applicable to both cardiorespiratory and resistance exercise, that consists of five exercise intensities (Very Low, Low, Moderate, High, and Very High) and five descriptors for the corresponding perception of effort (very easy, easy, somewhat hard, hard, and very hard).

We do not anticipate that this is the "final word" on the topic, but we do hope this expert statement will be an important "first step" in harmonizing the descriptions of exercise intensity across the fields of physical activity for public health, exercise science, and sport science. We do anticipate that there will be some resistance to altering long-established terminology. These respectful conversations, and further engagement with relevant groups on this topic, will be another important outcome of this document.

Finally, we acknowledge the need for markers of exercise intensity that can be used to prescribe exercise at a population level. However, we are not able to recommend the markers that appear in many exercise guidelines (e.g., %$\dot{V}O_{2max}$, %HRmax, %HRR, and METs). Given that this is an evidence-guided expert statement, it did not seem appropriate to recommend "flawed but practical" markers that do not achieve category-specific cardiovascular and metabolic responses in all (or even most) individuals. We hope that this expert statement stimulates greater research on this topic.

This article is being published as an official pronouncement of the American College of Sports Medicine. This pronouncement was reviewed for the American College of Sports Medicine by members-at-large and the Pronouncements Committee. Care has been taken to confirm the accuracy of the information present and to describe generally accepted practices. However, the authors, editors, and publisher are not responsible for errors or omissions or for any consequences from the application of the information in this publication and make no warranty, expressed or implied, with respect to the currency, completeness, or accuracy of the contents of the publication. The application of this information in a particular situation remains the professional responsibility of the practitioner; the clinical treatments described and recommended may not be considered absolute and universal recommendations. Given space restraints, it was not possible to cite all relevant articles regarding this topic. This work was supported by a National Health and Medical Research Council grant to D. B. (GNT2013427). M. G. is an advisor to and holds equity in Longevity League, Ltd., a US-based company whose services in part relate to exercise.

REFERENCES

1. Piercy KL, Troiano RP, Ballard RM, et al. The Physical Activity Guidelines for Americans. *JAMA*. 2018;320(19):2020–8.
2. DiPietro L, Buchner DM, Marquez DX, Pate RR, Pescatello LS, Whitt-Glover MC. New scientific basis for the 2018 US Physical Activity Guidelines. *J Sport Health Sci*. 2019;8(3):197–200.
3. Garber CE, Blissmer B, Deschenes MR, et al. Quantity and quality of exercise for developing and maintaining cardiorespiratory, musculoskeletal, and neuromotor fitness in apparently healthy adults: guidance for prescribing exercise. *Med Sci Sports Exerc*. 2011;43(7):1334–59.
4. Bangsbo J. Performance in sports—with specific emphasis on the effect of intensified training. *Scand J Med Sci Sports*. 2015;25(Suppl. 4):88–99.
5. Busso T. Variable dose–response relationship between exercise training and performance. *Med Sci Sports Exerc*. 2003;35(7):1188–95.
6. Pedersen BK, Saltin B. Evidence for prescribing exercise as therapy in chronic disease. *Scand J Med Sci Sports*. 2006;16(Suppl. 1):3–63.
7. Deloitte Access Economics. Value of Accredited Exercise Physiologists in Australia. 2016. Available at: https://www.deloitte.com/au/en/services/economics/perspectives/value-exercise-physiologists-australia.html. Accessed November 9, 2024.
8. Guillon M, Rochaix L, Dupont J-CK. Cost-effectiveness of interventions based on physical activity in the treatment of chronic conditions: a systematic literature review. *Int J Technol Assess Health Care*. 2018;34(5):481–97.
9. Physical Activity Guidelines Advisory Committee. *Physical Activity Guidelines Advisory Committee Report*. U.S. Department of Health and Human Services; 2018. Available from: U.S. Department of Health and Human Services.
10. Booth FW, Roberts CK, Thyfault JP, Ruegsegger GN, Toedebusch RG. Role of inactivity in chronic diseases: evolutionary insight and pathophysiological mechanisms. *Physiol Rev*. 2017;97(4):1351–402.
11. Watson SL, Weeks BK, Weis LJ, Harding AT, Horan SA, Beck BR. High-intensity resistance and impact training improves bone mineral density and physical function in postmenopausal women with osteopenia and osteoporosis: the LIFTMOR randomized controlled trial. *J Bone Miner Res*. 2018;33(2):211–20.
12. Hayes SC, Newton RU, Spence RR, Galvão DA. The Exercise and Sports Science Australia position statement: exercise medicine in cancer management. *J Sci Med Sport*. 2019;22(11):1175–99.

13. Singh F, Newton RU, Galvão DA, Spry N, Baker MK. A systematic review of pre-surgical exercise intervention studies with cancer patients. *Surg Oncol*. 2013;22(2):92–104.
14. Schumacher O, Galvão DA, Taaffe DR, et al. Effect of exercise adjunct to radiation and androgen deprivation therapy on patient-reported treatment toxicity in men with prostate cancer: a secondary analysis of 2 randomized controlled trials. *Pract Radiat Oncol*. 2021;11(3):215–25.
15. Academy of Royal Medical Colleges. Exercise: the miracle cure and the role of the doctor in promoting it. 2015. Available at: https://www.aomrc.org.uk/wp-content/uploads/2016/03/Exercise_the_Miracle_Cure_0215.pdf. Accessed November 9, 2024.
16. Aune D, Norat T, Leitzmann M, Tonstad S, Vatten LJ. Physical activity and the risk of type 2 diabetes: a systematic review and dose–response meta-analysis. *Eur J Epidemiol*. 2015;30(7):529–42.
17. Aune D, Schlesinger S, Leitzmann MF, et al. Physical activity and the risk of heart failure: a systematic review and dose–response meta-analysis of prospective studies. *Eur J Epidemiol*. 2021;36(4):367–81.
18. Chastin S, McGregor D, Palarea-Albaladejo J, et al. Joint association between accelerometry-measured daily combination of time spent in physical activity, sedentary behaviour and sleep and all-cause mortality: a pooled analysis of six prospective cohorts using compositional analysis. *Br J Sports Med*. 2021;55(22):1277–85.
19. Winter EM, Abt G, Brookes FC, et al. Misuse of "power" and other mechanical terms in sport and exercise science research. *J Strength Cond Res*. 2016;30(1):292–300.
20. Staunton CA, Abt G, Weaving D, Wundersitz DW. Misuse of the term 'load'in sport and exercise science. *J Sci Med Sport*. 2021;25(5):439–44.
21. Tipton CM. The history of "Exercise Is Medicine" in ancient civilizations. *Adv Physiol Educ*. 2014;38(2):109–17.
22. ACSM. *Guidelines for Graded Exercise Testing and Exercise Prescription*. Philadelphia (PA), Lea & Febiger; 1975.
23. Bull FC, Al-Ansari SS, Biddle S, et al. World Health Organization 2020 guidelines on physical activity and sedentary behaviour. *Br J Sports Med*. 2020;54(24):1451–62.
24. ACSM. *ACSM's Guidelines for Exercise Testing and Prescription*. 11th ed. Philadelphia (PA): Lippincott Williams & Wilkins; 2020.
25. Norton K, Norton L, Sadgrove D. Position statement on physical activity and exercise intensity terminology. *J Sci Med Sport*. 2010;13(5):496–502.
26. Thompson W, Gordon N, Pescatello L. *ACSM's Guidelines for Exercise Testing and Prescription*. Chicago (IL): Lippincott Williams & Wilkins.; 2009.
27. US Department of Health and Human Services. *Physical Activity and Health: A Report of the Surgeon General*. Washington (DC): US Department of Health and Human Services, Centers for Disease Control; 1996.
28. Caspersen CJ, Powell KE, Christenson GM. Physical activity, exercise, and physical fitness: definitions and distinctions for health-related research. *Public Health Rep*. 1985;100(2):126–31.
29. Loy JW. The nature of sport: a definitional effort. *Quest*. 1968;10(1):1–15.
30. Ross R, Blair SN, Arena R, et al. Importance of assessing cardiorespiratory fitness in clinical practice: a case for fitness as a clinical vital sign: a scientific statement from the American Heart Association. *Circulation*. 2016;134(24):e653–e99.
31. Poole DC, Ward SA, Gardner GW, Whipp BJ. Metabolic and respiratory profile of the upper limit for prolonged exercise in man. *Ergonomics*. 1988;31(9):1265–79.
32. Heymsfield SB, Brown J, Ramirez S, et al. Are lean body mass and fat-free mass the same or different body components? A critical perspective. *Adv Nutr*. 2024;15(12):100335.
33. Institute of Medicine (US) Committee on Military Nutrition Research. Body composition and physical performance: applications for the military services. Marriott BM, Grumstrup-Scott J, eds. Washington (DC): National Academies Press (US); 1990.
34. Ackland TR, Lohman TG, Sundgot-Borgen J, et al. Current status of body composition assessment in sport: review and position statement on behalf of the Ad Hoc Research Working Group on Body Composition Health and Performance, under the auspices of the I.O.C. Medical Commission. *Sports Med*. 2012;42(3):227–49.
35. Holmes CJ, Racette SB. The utility of body composition assessment in nutrition and clinical practice: an overview of current methodology. *Nutrients*. 2021;13(8):2493.
36. Ellis KJ. (2000).Human body composition: in vivo methods. *Physiol Rev*. 2000;80(2):649–80.
37. Knuttgen HG, Kraemer WJ. Terminology and measurement. *J Appl Sport Sci Res*. 1987;1(1):1–10.
38. Kraemer WJ, Newton RU. Training for muscular power. *Phys Med Rehabil Clin N Am*. 2000;11(2):341–68.
39. Moritani T. Motor unit and motoneurone excitability during explosive movement. In: Komi PV, editor. *Strength and Power in Sport*. Oxford, UK: Blackwell Scientific Publications; 1992: p. 37.
40. Powers SK, Howley ET. *Exercise Physiology: Theory and Application to Fitness and Performance*. 3rd ed. Chicago: Brown & Benchmark; 1997.
41. Ratamess N. *ACSM's Foundations of Strength Training and Conditioning*. Philadelphia (PA): Lippincott Williams & Wilkins; 2012.
42. Fleck SJ, Kraemer W. *Designing Resistance Training Programs*. Champaign (IL): Human Kinetics; 1997.
43. McHugh MP, Kremenic IJ, Fox MB, Gleim GW. The role of mechanical and neural restraints to joint range of motion during passive stretch. *Med Sci Sports Exerc*. 1998;30(6):928–32.
44. Liemohn W. Flexibility and muscular strength. *J Phys Educ Recreat Dance*. 1998;59(7):37–40.
45. Barnett LM, Lai SK, Veldman SLC, et al. Correlates of gross motor competence in children and adolescents: a systematic review and meta-analysis. *Sports Med*. 2016;46(11):1663–88.
46. King-Dowling S, Proudfoot NA, Cairney J, Timmons BW. Motor competence, physical activity, and fitness across early childhood. *Med Sci Sports Exerc*. 2020;52(11):2342–8.
47. Stodden DF, Goodway JD, Langendorfer SJ, et al. A developmental perspective on the role of motor skill competence in physical activity: an emergent relationship. *Quest*. 2008;60(2):290–306.
48. Birk TJ, Birk CA. Use of ratings of perceived exertion for exercise prescription. *Sports Med*. 1987;4(1):1–8.
49. Pageaux B. Perception of effort in exercise science: definition, measurement and perspectives. *Eur J Sport Sci*. 2016;16(8):885–94.
50. Wen CP, Wai JPM, Tsai MK, et al. Minimum amount of physical activity for reduced mortality and extended life expectancy: a prospective cohort study. *Lancet*. 2011;378(9798):1244–53.
51. Riebe D, Franklin BA, Thompson PD, et al. Updating ACSM's recommendations for exercise preparticipation health screening. *Med Sci Sports Exerc*. 2015;47(8):2473–9.
52. Lie ØH, Dejgaard LA, Saberniak J, et al. Harmful effects of exercise intensity and exercise duration in patients with arrhythmogenic cardiomyopathy. *JACC Clin Electrophysiol*. 2018;4(6):744–53.
53. Bauman AE, Nau T, Cassidy S, Gilbert S, Bellew W, Smith BJ. Physical activity surveillance in Australia: standardisation is overdue. *Aust N Z J Public Health*. 2021;45(3):189–92.
54. Mezzani A, Hamm LF, Jones AM, et al. Aerobic exercise intensity assessment and prescription in cardiac rehabilitation: a joint position statement of the European Association for Cardiovascular Prevention and Rehabilitation, the American Association of Cardiovascular and Pulmonary Rehabilitation and the Canadian Association of Cardiac Rehabilitation. *Eur J Prev Cardiol*. 2013;20(3):442–67.
55. Tremblay MS, Aubert S, Barnes JD, et al. Sedentary Behavior Research Network (SBRN)—terminology consensus project process and outcome. *Int J Behav Nutr Phys Act*. 2017;14(1):75.
56. U.S. Department of Health and Human Services. Physical Activity Guidelines for Americans. 2018. Available at: https://odphp.health.gov/sites/default/files/2019-09/Physical_Activity_Guidelines_2nd_edition.pdf. Accessed November 9, 2024.

57. UK Chief Medical Officers. *Physical Activity Guidelines*. United Kindom: Department of Health and Social Care, Llwodraeth Cymru Welsh Government, Department of Health Northern Ireland and the Scottish Government; 2019.
58. Poole DC, Jones AM. Oxygen uptake kinetics. *Compr Physiol*. 2012;2(2):933–96.
59. Burnley M, Jones AM. Power–duration relationship: physiology, fatigue, and the limits of human performance. *Eur J Sport Sci*. 2018;18(1):1–12.
60. Midgley AW, McNaughton LR, Jones AM. Training to enhance the physiological determinants of long-distance running performance: can valid recommendations be given to runners and coaches based on current scientific knowledge? *Sports Med*. 2007;37(10):857–80.
61. Casado A, Foster C, Bakken M, Tjelta LI. Does lactate-guided threshold interval training within a high-volume low-intensity approach represent the "next step" in the evolution of distance running training? *Int J Environ Res Public Health*. 2023;20(5):3782.
62. Jamnick NA, Pettitt RW, Granata C, Pyne DB, Bishop DJ. An examination and critique of current methods to determine exercise intensity. *Sports Med*. 2020;50(10):1729–56.
63. Buchheit M, Laursen PB. High-intensity interval training, solutions to the programming puzzle: part I: cardiopulmonary emphasis. *Sports Med*. 2013;43(5):313–38.
64. Bennie JA, Shakespear-Druery J, De Cocker K. Muscle-strengthening exercise epidemiology: a new frontier in chronic disease prevention. *Sports Med Open*. 2020;6(1):40.
65. Kistler-Fischbacher M, Weeks BK, Beck BR. The effect of exercise intensity on bone in postmenopausal women (part 2): a meta-analysis. *Bone*. 2021;143:115697.
66. Izquierdo M, Merchant R, Morley J, et al. International Exercise Recommendations in Older Adults (ICFSR): expert consensus guidelines. *J Nutr Health Aging*. 2021;25(7):824–53.
67. Howley ET. Type of activity: resistance, aerobic and leisure versus occupational physical activity. *Med Sci Sports Exerc*. 2001;33(6 Suppl):S364–9 discussion S419–20.
68. Williams MA, Haskell WL, Ades PA, et al. Resistance exercise in individuals with and without cardiovascular disease: 2007 update: a scientific statement from the American Heart Association Council on Clinical Cardiology and Council on Nutrition, Physical Activity, and Metabolism. *Circulation*. 2007;116(5):572–84.
69. Robertson RJ, Goss FL, Rutkowski J, et al. Concurrent validation of the OMNI perceived exertion scale for resistance exercise. *Med Sci Sports Exerc*. 2003;35(2):333–41.
70. MacInnis MJ, Gibala MJ. Physiological adaptations to interval training and the role of exercise intensity. *J Physiol*. 2017;595(9): 2915–30.
71. Borg G. *Physical Performance and Perceived Exertion*. Lundi (Sweden): Gleerup; 1962.
72. Katch V, Weltman A, Sady S, Freedson P. Validity of the relative percent concept for equating training intensity. *Eur J Appl Physiol*. 1978;39(4):219–27.
73. Poole DC, Rossiter HB, Brooks GA, Gladden LB. The anaerobic threshold: 50+ years of controversy. *J Physiol*. 2021;599(3): 737–67.
74. Jamnick NA, Botella J, Pyne DB, Bishop DJ. Manipulating graded exercise test variables affects the validity of the lactate threshold and VO_{2peak}. *PLoS One*. 2018;13(7):e0199794.
75. Faude O, Kindermann W, Meyer T. Lactate threshold concepts: how valid are they? *Sports Med*. 2009;39(6):469–90.
76. Jones AM, Burnley M, Black MI, Poole DC, Vanhatalo A. The maximal metabolic steady state: redefining the 'gold standard'. *Physiol Rep*. 2019;7(10):e14098.
77. Galán-Rioja MÁ, Gonzalez-Mohino F, Poole DC, González-Ravé JM. Relative proximity of critical power and metabolic/ventilatory thresholds: systematic review and meta-analysis. *Sports Med*. 2020;50(10):1771–83.
78. Keir DA, Mattioni Maturana F, Iannetta D, Murias JM. Comment on: Relative proximity of critical power and metabolic/ventilatory thresholds: systematic review and meta-analysis. *Sports Med*. 2021; 51(2):367–8.
79. Garcia-Tabar I, Gorostiaga EM. Comment on: Relative proximity of critical power and metabolic/ventilatory thresholds: systematic review and meta-analysis. *Sports Med*. 2021;51(9): 2011–3.
80. Keir DA, Fontana FY, Robertson TC, et al. Exercise intensity thresholds: identifying the boundaries of sustainable performance. *Med Sci Sports Exerc*. 2015;47(9):1932–40.
81. Galán-Rioja MÁ, González-Mohíno F, Poole DC, González-Ravé JM. Authors' reply to Ibai García-Tabar and Esteban M. Gorostiaga: comment on "Relative proximity of critical power and metabolic/ ventilatory thresholds: systematic review and meta-analysis". *Sports Med*. 2021;51(9):2015–6.
82. Mann T, Lamberts RP, Lambert MI. Methods of prescribing relative exercise intensity: physiological and practical considerations. *Sports Med*. 2013;43(7):613–25.
83. Scharhag-Rosenberger F, Meyer T, Gäßler N, Faude O, Kindermann W. Exercise at given percentages of VO_{2max}: heterogeneous metabolic responses between individuals. *J Sci Med Sport*. 2010;13(1):74–9.
84. Vollaard NBJ, Constantin-Teodosiu D, Fredriksson K, et al. Systematic analysis of adaptations in aerobic capacity and submaximal energy metabolism provides a unique insight into determinants of human aerobic performance. *J Appl Physiol (1985)*. 2009;106(5): 1479–86.
85. Iannetta D, Keir DA, Fontana FY, et al. Evaluating the accuracy of using fixed ranges of METs to categorize exertional intensity in a heterogeneous group of healthy individuals: implications for cardiorespiratory fitness and health outcomes. *Sports Med*. 2021;51(11): 2411–21.
86. Halperin I, Emanuel A. Rating of perceived effort: methodological concerns and future directions. *Sports Med*. 2020;50(4):679–87.
87. Steed J, Gaesser GA, Weltman A. Rating of perceived exertion and blood lactate concentration during submaximal running. *Med Sci Sports Exerc*. 1994;26(6):797–803.
88. Scherr J, Wolfarth B, Christle JW, Pressler A, Wagenpfeil S, Halle M. Associations between Borg's rating of perceived exertion and physiological measures of exercise intensity. *Eur J Appl Physiol*. 2013;113(1):147–55.
89. Demello JJ, Cureton KJ, Boineau RE, Singh MM. Ratings of perceived exertion at the lactate threshold in trained and untrained men and women. *Med Sci Sports Exerc*. 1987;19(4):354–62.
90. Goss FL, Robertson RJ, Gallagher M Jr., Piroli A, Nagle EF. Response normalized OMNI rating of perceived exertion at the ventilatory breakpoint in division I football players. *Percept Mot Skills*. 2011;112(2):539–48.
91. Irving BA, Rutkowski J, Brock DW, et al. Comparison of Borg- and OMNI-RPE as markers of the blood lactate response to exercise. *Med Sci Sports Exerc*. 2006;38(7):1348–52.
92. Nakamura FY, Pereira G, Chimin P, Siqueira-Pereira TA, Simões HG, Bishop DJ. Estimating the perceived exertion threshold using the OMNI scale. *J Strength Cond Res*. 2010;24(6): 1602–8.
93. Bok D, Rakovac M, Foster C. An examination and critique of subjective methods to determine exercise intensity: the Talk Test, Feeling Scale, and rating of perceived exertion. *Sports Med*. 2022;52(9): 2085–109.
94. Doust J, Patrick J. The limitation of exercise ventilation during speech. *Respir Physiol*. 1981;46(2):137–47.
95. Woltmann ML, Foster C, Porcari JP, et al. Evidence that the talk test can be used to regulate exercise intensity. *J Strength Cond Res*. 2015;29(5):1248–54.
96. Foster C, Porcari JP, Gibson M, et al. Translation of submaximal exercise test responses to exercise prescription using the Talk Test. *J Strength Cond Res*. 2009;23(9):2425–9.

97. Zanettini R, Centeleghe P, Franzelli C, et al. Validity of the talk test for exercise prescription after myocardial revascularization. *Eur J Prev Cardiol*. 2013;20(2):376–82.
98. Scott BR, Duthie GM, Thornton HR, Dascombe BJ. Training monitoring for resistance exercise: theory and applications. *Sports Med*. 2016;46(5):687–98.
99. Cooke DM, Haischer MH, Carzoli JP, et al. Body mass and femur length are inversely related to repetitions performed in the back squat in well-trained lifters. *J Strength Cond Res*. 2019;33(3):890–5.
100. Lovegrove S, Hughes LJ, Mansfield SK, Read PJ, Price P, Patterson SD. Repetitions in reserve is a reliable tool for prescribing resistance training load. *J Strength Cond Res*. 2022;36(10):2696–700.
101. Refalo MC, Helms ER, Hamilton DL, Fyfe JJ. Influence of resistance training proximity-to-failure, determined by repetitions-in-reserve, on neuromuscular fatigue in resistance-trained males and females. *Sports Med Open*. 2023;9(1):10.
102. Zourdos MC, Klemp A, Dolan C, et al. Novel resistance training–specific rating of perceived exertion scale measuring repetitions in reserve. *J Strength Cond Res*. 2016;30(1):267–75.