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Let Them Roam Free?

Physiological and Psychological Evidence for the Potential of Self-Selected Exercise Intensity in Public Health

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Contents

Abstract

In recommending physical activity for public health, authors have advocated either an approach in which the participant is to follow a prescription developed by a professional or an approach based on the participants' own preferences. This review explores the potential for convergence between these two approaches by examining: (i) whether the exercise intensity that participants select is within the range recommended by the American College of Sports Medicine for the development and maintenance of cardiorespiratory fitness and health; (ii) what is known about the determinants of self-selected intensity and the factors underlying interindividual differences; and (iii) the psychological consequences of imposing a level of intensity compared with allowing participants to select their preferred level. The results indicate that, among middle-aged or older, sedentary or obese participants, or those in cardiac rehabilitation, self-selected exercise intensities are, on average, within the recommended range. However, some individuals select levels well below the recommended range and others select near-maximal levels. Most individuals apparently select intensities proximal to their ventilatory or lactate threshold, presumably because higher intensities would reduce pleasure. The factors underlying the large interindividual differences in self-selected intensity remain poorly understood. Imposed intensities lead to declines in pleasure, even when they exceed the self-selected level by a small amount. These results demonstrate the compatibility of prescription-based and preference-based

approaches. Public health practitioners can consider self-selected intensity as an appropriate option.

Physical inactivity represents one of the greatest public health challenges for most industrialized nations. The WHO[1] estimates that the annual human toll attributed to physical inactivity amounts to approximately 1.9 million deaths and 19 million disability-adjusted life-years lost. In the US, according to the final review of the Healthy People 2000 programme,[2] "the proportion of the population reporting physical activity has remained essentially unchanged, and progress is very limited" (p. 29). According to data from the National Health Interview Survey[3,4] (a nationwide in-person household survey), only 31% of adults aged >18 years engage in regular physical activity (i.e. light-to-moderate activity for at least 30 minutes on at least 5 days per week or vigorous activity for at least 20 minutes on at least 3 days per week). On the other hand, 39% do not participate in any type of leisure-time physical activity and 62% never participate in vigorous activity. In England, according to the 2003 Health Survey,[5] 37% of men and 24% of women reported meeting the recommended physical activity target (moderate activity for at least 30 minutes on at least 5 days per week). On the other hand, 21% of men and 26% of women had not done any moderate physical activity (for at least 30 continuous minutes) in the 4 weeks preceding the interview. In Australia, according to data from the National Physical Activity Survey,[6] 15% of adults reported no leisure-time physical activity during the previous week and another 40% accumulated less than 150 minutes.

Efforts to understand the behavioural mechanisms underlying the processes of engaging in, adhering to and disengaging from physical activity have not been very successful and, accordingly, interventions designed to increase public participation and adherence have yielded only modest results.[7,8] The motivational significance of the physical activity stimulus itself represents one of the most understudied and underexploited factors possibly underlying physical activity behaviour. Simply put, do the subjective experiences that people derive from their participation in physical activity foster a willingness or desire to repeat this behaviour in the future? Common sense and the so-called 'hedonic' theory of motivation[9] would suggest that, if people derive pleasure, a sense of energy or enjoyment, they would probably seek to repeat this activity. On the other hand, if they derive displeasure, discomfort, pain or a sense of exhaustion, the chances of them repeating the activity or adhering to it over the long run would be diminished. Recent research has provided evidence of both cross-sectional and prospective associations between affect and physical activity behaviour.[10-12]

Perhaps the main reason for the persistent inattention to the issue of the motivational significance of the physical activity stimulus is the dualistic disciplinary chasm within the exercise sciences. Motivation for physical activity is studied by exercise psychologists, who have traditionally directed their attention mainly to social-cognitive factors (e.g. perceived benefits, perceived barriers, self-efficacy, social support) and, more recently, ecological factors (e.g. the built environment). For various reasons, exercise *per se* has not received systematic attention in exercise psychology research; consequently, the motivational implications of the exercise stimulus itself have been largely ignored. On the other hand, determining the appropriate attributes of the exercise stimulus for public health and issuing recommendations to the public is something that has traditionally been considered within the purview of exercise physiology (at least initially, *clinical* exercise physiology). In carrying out these tasks, exercise physiologists have usually taken into account two factors, namely what types and 'doses' of physical activity are effective and/or safe, essentially disregarding whether the recommended stimuli are also conducive to motivation and adherence. The lack of overlap between the health-oriented exercise psychology and health-oriented exercise physiology literature and the lack of interdisciplinary communication between the two respective groups of experts continues to be as prevalent as it is counterproductive. This seems especially problematic considering the failure of the exercise sciences to advance the common cause of promoting physical activity to larger segments of the population. The overarching theme of the present review is that, in developing physical activity recommendations for public health, physiological and psychological considerations can and should be balanced in a meaningful manner.

1. Pushy Types, Philanthropists and Compromisers

In the classic paper in which they introduced the concept of heart rate reserve more than a half century ago, Karvonen et al.[13] asserted that an improvement in cardiorespiratory fitness can occur only when the intensity of training is "at or slightly above" a "critical limit" (p. 310). That limit was determined to be at 60% of heart rate reserve. What is mysterious, however, is that none of the six participants in their study trained at an intensity below 60% of heart rate reserve, therefore the study could not really have provided concrete evidence that 60% represents such a 'critical limit'. Nevertheless, noting that "in order to cause an increase in the maximum oxygen uptake, training must be intense," Karvonen et al.[13] cautioned that "misguided philanthropism" in the management of training programmes "may deprive them of one of their major effects" (p. 311). Interestingly, although many years have passed since then, a recent review concluded that 45% of oxygen uptake reserve should be considered "the minimal effective intensity for eliciting improvements in cardiorespiratory fitness in patients with coronary heart disease," not because lower intensities have been shown to be ineffective, but rather because studies examining intensities below this level are not available.

Echoing the caution of Karvonen et al.[13] against "misguided philanthropism" half a century later, a best-selling self-help book[15] on using exercise to improve weight management, health and emotional well-being notes that exercise should be performed "at the highest intensity that is safe." To be effective, exercise allegedly must induce "a definite feeling of fatigue" (p. 113) and take people "past [their] level of comfort" (p. 115). Accordingly, exercise practitioners are warned that "when most people are left to their own devices, they will adopt an exercise intensity that is too low" (pp. 108–9). The clear implication is that most people must be 'pushed' by their personal trainer, exercise leader or rehabilitation specialist if they are to reach an effective range of intensity and unlock the healthful potential of exercise.

The historical origins of this deep-rooted belief in the necessity of high-intensity exercise and, by implication, the external imposition or monitoring of intensity are unclear. Some evidence shows that most individuals have a rather poor ability to estimate their heart rate, reproduce a certain level of exercise intensity, or accurately recall their level of exercise intensity.[16-19] This is of particular concern in the context of cardiac rehabilitation, where strenuous exercise can increase the risk of dangerous, possibly fatal, complications. However, the data on whether most individuals have a tendency to under- or overexert themselves seem conflicting. For example, Kollenbaum[17] found that approximately 40% of cardiac patients undergoing exercise rehabilitation underestimated their heart rate (increasing the likelihood of exceeding their target), while about 10% overestimated it (increasing the likelihood of falling short of their target). In contrast, Kosiek et al.[19] found that, despite reporting similar levels of perceived exertion, 64% of cardiac rehabilitation patients fell short of their target heart rate (by as many as 29 beats/min), 17% exceeded their target range (by as many as 20 beats/min), and only 16% were within the target range (the other 3% were inconsistent).

Thus, it is perhaps reasonable to assume that the continued paradigmatic emphasis on the concept of a prescribed 'target' range of exercise intensity[20] is the product of (i) the apparently widely held notion that, if the intensity is 'too low', it will not be effective (or, at least, not as effective as higher intensity) and (ii) the belief that most individuals are in need of close external monitoring to regulate their intensity, since most inherently lack accurate self-monitoring skills. The prescriptive approach, in conjunction with external monitoring and regulation of intensity, was the method devised to ensure that individuals would exercise within a range of intensity that is both effective and safe.

Although these are reasonable concerns, some questions can also be raised. Firstly, the level of intensity that may be 'too low' can vary substantially depending on the health- or fitness-related outcome of interest. Not all outcomes necessitate high intensity, and in some cases high intensity may even be ineffective or detrimental. After all, research evidence on the dose-response relationship between exercise intensity and many health outcomes remains scant. Secondly, the fact that most individuals cannot accurately estimate their heart rate does not necessarily mean that when asked to self-regulate their exercise intensity the level of intensity they select is not within the range considered effective and safe by current standards. Studies have shown that responses to exercise training, such as gains in aerobic fitness, in both healthy[21] and clinical samples[22] are not significantly different when the participants exercise within a target range of intensity based on external monitoring of heart rate, or when they self-regulate their intensity based on general instructions on maintaining a certain level of perceived exertion.

A decade after the advent of the physical activity guidelines by the Centers for Disease Control and Prevention and the American College of Sports Medicine (ACSM),[23] which attempted to shift the paradigm in public health from prescribed exercise of a specific 'target' dose to lifestyle physical activity of moderate intensity,[24] calls for regimented high-intensity training are re-emerging. Building upon earlier[25] and more recent evidence,[26] a central argument underpinning this trend is that the higher intensity affords greater health benefits. For example, according to an extensive review[27] of the cardioprotective effects of moderate and high-intensity exercise, greater improvements are found after vigorous (i.e. ≥60% of maximal aerobic capacity) than after moderate exercise for diastolic blood pressure, glucose control and aerobic capacity. On the other hand, the level of intensity does not seem to influence the improvements in systolic blood pressure, lipid profile or body fat loss. Based on this evidence, the authors concluded that "the preponderance of evidence favors more cardioprotective benefits from vigorous than from moderate intensity exercise" (p. 145). However, in this assessment, the fact that "moderate-intensity physical activities are more likely to be continued than are high-intensity activities" (p. 243), as had been determined by the National Institutes of Health Development Panel on Physical Activity and Cardiovascular Health,[28] was not taken into consideration. Clearly, any cardioprotective effects would be nullified if the participants did not adhere to or discontinued the activity programme.

O'Donovan et al.[29] performed a 24-week study in which after the initial 8-week induction phase one group of formerly sedentary middle-aged men completed three 400 kcal sessions per week at 60% maximal oxygen uptake ($\dot{V}O_{2max}$), whereas another group completed three 400 kcal sessions per week at 80% $\dot{V}O_{2max}$. By the 24th week, the members of the 60% group had increased their $\dot{V}O_{2max}$ by 14% (4.85 mL/kg/min), whereas the members of the 80% group had increased theirs by 21% (7.14 mL/kg/min). In addition, the 80% group showed somewhat larger decreases in total cholesterol, low-density lipoprotein cholesterol and non-high-density lipoprotein cholesterol, which, however, were probably due to their somewhat higher pre-intervention values (there were no differences at the end of the intervention). The authors commented that the 80% $\dot{V}O_{2max}$ intervention was "more effective in improving cardiorespiratory fitness" and that its members were able to expend 1200 kcal per week by exercising only three times per week for 30–40 minutes, whereas had they been using brisk walking, they would have needed 30 minutes per day, 7 days per week. While the emphasis was on these outcomes, no particular mention was made of the fact that 36% of the participants in the 60% group and 41% of those in the 80% group had dropped out before the 24th week.

Besides the maximization of fitness and health gains, contemporary proponents of the high-intensity training approach also raise two motivational issues. Firstly, a bout of exercise performed at higher intensity is more time efficient than one at a lower intensity, thus reducing the overall time commitment that exercise requires. Secondly, it is argued that many individuals discontinue regular activity mostly because they do not get visible results quickly. Both arguments appear reasonable. Lack of time consistently ranks in population surveys as a top perceived barrier to participation in physical activity.[30] Similarly, many individuals begin activity programmes with high expectations, and the perceived failure to reach such ambitious goals commonly leads to dropout.[31,32] Pursuing this line of argument under the heading "a little pain for a lot of gain," Gibala and McGee[33] wrote:

> *Given that lack of time is such a common barrier to exercise participation, exercise prescription innovations that yield benefits with minimal time commitments represent a potentially valuable approach to increasing population activity levels and population health. [High-intensity interval training] is often dismissed outright as unsafe, unpractical, or intolerable for many individuals. However, there is growing appreciation of the potential for intense interval-based training to stimulate improvements in health and fitness in a range of populations, including persons with various disease conditions (pp. 61–62).*

The promise of the "improvements in health and fitness," however, comes with the crucial caveat that the high-intensity interval training requires "an extremely high level of subject motivation" and that "given the extreme nature of the exercise, it is doubtful that the general population could safely or practically adopt the model" (p. 62).[33]

Representing a different point of view, other authors have long made a case for the need to build physical activity interventions on the basis of what the participants prefer. For instance, according to King and Martin,[34] "ways of enhancing enjoyability include the tailoring of … the actual exercise regimen … to individual preferences" (p. 447). When King et al.[35] surveyed 399 employees of the Lockheed Corporation, they found that, regardless of whether the respondents were current or past exercisers or non-exercisers, the reported likelihood of engaging in exercise was highest for exercise performed autonomously, on one's own. Likewise, when Wilcox et al.[36] surveyed 1877 middle-aged and 1526 older adults, they found that 69% and 67%, respectively, preferred to exercise on their own. Along the same lines, King et al.[30] surveyed 2912 women aged >40 years from various racial-ethnic groups and found that 62% expressed a preference for exercising on their own with some instruction. A telephone survey of 286 Australian women aged 50–64 years also showed that 68% preferred 'going it alone'.[37]

The reasons for this overwhelming preference for autonomously performed activity are not yet clear. According to self-determination theory,[38] perceived autonomy is one of the basic psychological needs. Consequently, maintaining a sense of perceived autonomy is likely to be experienced as pleasant and, therefore, self-rewarding and conducive to intrinsic motivation. Conversely, the loss of perceived autonomy inherent in an externally imposed exercise prescription (e.g. externally dictated and controlled exercise intensity) is likely to be experienced as unpleasant and, therefore, also likely to have a negative motivational impact. Initial evidence shows that having the ability to select one's preferred mode of exercise is associated with improved affective responses.[39-41] Furthermore, perceived choice in determining the attributes of an exercise programme is associated with better attendance.[42] Similarly, having the flexibility to accumulate physical activity in bouts as short as 5 or 6 minutes can raise not only the amount of activity that individuals perform but also their cardiorespiratory fitness.[43,44]

Several authors have specifically focused on the element of exercise intensity, arguing that allowing participants to select their preferred intensity should be associated with pleasure. For example, according to Morgan,[45] "it is quite probable that investigators who ask participants in research studies to exercise at their *customary* or *preferred* level of intensity would be more likely to observe positive psychological outcomes than investigators who require all individuals to exercise at the same relative intensity (e.g. 70% $\dot{V}O_{2max}$), because the latter (i.e. nonpreferred) might be perceived as aversive" (p. 9). In their review on the effects of exercise on mood states, Berger and Motl[46] described a similar idea:

> *[An] individual characteristic that may affect mood alteration is preferred level of exertion. Although many individuals follow the fitness guidelines of the American College of Sports Medicine or the workout suggestions of personal trainers, these "training" guidelines may not be conducive to mood improvements. To maximize the psychological benefits of exercise, an individual may need to exercise at an intensity that is personally enjoyable. There is a need to examine the differential effects of preferred level of exertion in comparison to other experimenter-selected intensities on mood alteration (p. 87).*

Taking this line of reasoning one step further, authors have suggested that, if a self-selected level of intensity is experienced as more pleasant than an imposed level of intensity, it follows that consistently having the freedom to regulate one's intensity should result in better adherence in the long run. Making this case, Dishman et al.[47] wrote:

> *Standard exercise prescription procedures titrate exercise intensity, usually at a constant pace, to yield a physiological or perceptual response indicative of optimal $\dot{V}O_2$ for training adaptations. This practice is opposed to allowing individuals to select a preferred work rate, whereby perceived exertion and physiological responses might vary. There is scientific consensus that preferred and perceived exertion are possible determinants of self-selected exercise intensity, that they are understudied, and that they are priority areas of research. Exercise prescriptions based on preferred intensities might increase adherence to exercise programmes (p. 783).*

Along similar lines, Dishman[48] added:

> *If a preferred intensity selected by a person is reliable and is within expected ranges for [ratings of perceived exertion] (e.g. 10–16 on Borg's 6–20 category scale) and relative tolerance for exercise (e.g. 40–75% of [peak oxygen uptake] or maximum [metabolic equivalents]), it should be safe and health-promoting for most healthy adults. A preferred intensity of exercise also may better promote adherence than a strict prescription based on more precise physiological criteria if those criteria conflict with a person's intensity preference (p. 1093; also see Dishman[49] p. 294).*

Likewise, in his proposal for a paradigmatic shift in the conceptualization and study of the problem of exercise adherence, Morgan[50] put forth a similar argument:

> *The idea of personalizing physical activity in such a way that each individual receives the optimal amount represents an ideal that is difficult to achieve if one elects to employ conventional exercise prescriptions. The idea that each person should exercise at a given percent of maximum, for a given number of minutes, and a given number of days per week, should in theory lead to recidivism rather than adherence. And, that is undoubtedly one of the reasons why adherence in physical activity programmes has been a problem for many years (p. 372–373).*

As is evident from these excerpts, two apparently distinct 'schools of thought' have emerged within the exercise sciences on how to approach the issue of recommending an appropriate level of physical activity intensity for public health. On the one hand, there are those who advocate a top-down (i.e. prescriptive) approach, based on high-intensity training. Within a margin of interindividual variation in adaptability, this approach promises high effectiveness in terms of health and/or fitness outcomes, as well as an accelerated rate for the accrual of these outcomes. However, this is admittedly 'not for everyone', as it has a high potential to discourage many of those who are not yet active, and to cause injury, discomfort or displeasure, and ultimately drop-out for many of those who become active.

Although information pertaining specifically to exercise is not yet available, studies on chronic pain have shown that developing a fear of an unpleasant or uncomfortable stimulus is a strong predictor of avoidance of that stimulus (i.e. unwillingness to repeatedly subject oneself to that aversive experience) and overall disability.[51] A relevant example is the construct of 'kinesiophobia', the fear of movement that commonly develops among individuals with chronic pain that is transiently exacerbated by physical activity (e.g. low-back pain or osteoarthritic pain of the knee). Not surprisingly, kinesiophobia has been shown to be associated with the avoidance of physical activity.[52,53] The consistent finding that high exercise intensity is associated with lower adherence[54-56] may reflect a similar mechanism, whereby high intensity is experienced as unpleasant or uncomfortable, in turn leading to avoidance or reduced intrinsic motivation for future participation.

On the other hand, some authors have advocated an approach that places emphasis mainly on long-term behavioural maintenance rather than on accelerated physiological effectiveness. Given the focus on behavioural maintenance, the extent to which physical activity is intrinsically pleasant and rewarding is a central consideration in this approach.

Given this somewhat polarized situation, with the two camps focusing on different elements and defining intervention success in different ways, finding or recognizing the common ground has become difficult. Nevertheless, it should be pointed out that voices calling for convergence and compromise have not been lacking. For example, Pollock et al.[57] were keenly aware of the importance of developing individualized prescriptions that balance physiological effectiveness on the one hand with enjoyment and pleasure (or tolerability) on the other. They wrote extensively on the need to provide physical activity programmes that not only "meet the criteria for improving and maintaining a sufficient level of physical fitness" but are also "enjoyable", "rewarding to the participant", and "preferably … fun" (pp. 121–122). Following a similar rationale, Dishman[58] wrote that "it is quite possible that some compromise between the ideal physiological prescription and a manageable behavioral prescription may be necessary to allow adherence to be sufficient for desired biological changes to occur" (p. 248). He further explained:[59]

> *Although exercise prescriptions based strictly on objective thresholds of energy demand or heart rate may optimize physiological adaptations, they may also minimize the chances that certain individuals will adhere to that prescription if other biological and psychological characteristics of the exerciser are ignored. In other words, from an adherence standpoint, a precise behavioral prescription may be equally as critical as a precise physiological prescription" (p. 174).*

Today, echoes of these earlier calls can be found in the guidelines issued by the ACSM.[20] Therein, it is acknowledged that, ultimately, "the most appropriate exercise prescription for a particular individual is the one that is most helpful in achieving … behavioral change" (p. 136). To accomplish this principal goal, taking into account individual differences in exercise 'preference' (e.g. pp. 135, 142, 146, 148, 149) is considered essential. For example, according to the guidelines, "individual preferences for exercise must be considered to improve the likelihood that the individual will adhere to the exercise program" (p. 142). However, one might argue that psychological considerations (i.e. affect, enjoyment, perceived autonomy, control and competence) should have been assigned an even more central role, having been considered as one of the basic pillars of the rationale underpinning the guidelines, alongside effectiveness and safety. A central aim of the present review is to highlight that the potential for convergence is substantial. Most importantly, there is now evidence that a physical activity stimulus can be effective, safe and pleasant, and therefore physiological and psychological considerations are compatible rather than mutually exclusive. Thus, the 'compromise' that Pollock and Dishman envisioned decades ago might now be easier to reach than ever.

2. Purposes of the Present Review

The first specific purpose of this review was to examine whether, when people are 'left to their own devices', they select exercise intensities that are conducive to cardiorespiratory fitness and health enhancement according to current ACSM guidelines.[20] This question is at the core of the conflict between ‘prescription-based’ and ‘preference-based’ approaches. If most individuals spontaneously select intensities recognized to confer physiological benefits, this would challenge the rationale of the prescriptive approach and the perceived need to ‘push’ individuals to reach ‘target’ thresholds of intensity.

The second specific purpose was to examine what is presently known about the determinants of self-selected intensity from various literatures. Of particular interest are the factors responsible for the marked differences commonly observed in the levels of exercise intensity selected by different individuals. Gaining a better understanding of such factors would lay the foundation for intervention efforts designed to prevent or correct extreme tendencies in either direction (i.e. selecting intensities that are too low to be effective or too high to be safe).

The third specific purpose of this review was to examine the psychological consequences of exercising at an imposed level of intensity, as opposed to a self-selected one. As noted earlier, the self-determination theory[38] would suggest that the lack of perceived autonomy and control that the external imposition of intensity entails would result in a less positive affective experience, with possibly negative motivational implications.

3. What Exercise Intensities do People Select when ‘Left to their Own Devices’?

Scientific bibliographic databases (i.e. PubMed, PsycINFO, Google Scholar, Thomson Reuters Science and Social Sciences Citation Index) were searched using the keywords ‘exercise’ and ‘physical activity’ in conjunction with such descriptors as ‘self-selected’, ‘self-paced’, ‘self-regulated’ or ‘preferred’. The abstracts were examined to determine the relevance of the studies to the topic of the present review. All potentially relevant articles were retrieved and read. Articles were then excluded if they did not provide adequate information or if the studies included important confounding factors. Excluded studies in the former category were those that: (i) did not report at least one of the physiological variables considered by the ACSM (i.e. percentage of maximal heart rate or heart rate reserve, percentage of $\dot{V}O_{2max}$ or oxygen uptake reserve, and ratings of perceived exertion); (ii) focused only on biomechanical or temporospatial (e.g. gait length and frequency) analyses of self-paced walking or running; (iii) were reported only in the form of an abstract; or (iv) included assessments of physiological indices only by an unreliable method (e.g. heart rate by palpation). Excluded studies in the latter category were those that: (i) examined samples of patients with muscular, skeletal or neurological conditions (including traumatic injuries) that severely impair ambulatory capacity; (ii) included experimental conditions that involved competition (e.g. self-regulation of running or cycling pace during a race); (iii) involved instructions to participants referring to being ‘in a hurry’ or in pursuit of an objective (e.g. as if to catch the bus, arrive at a meeting, or reach the post office before it closes for the day); or (iv) included other major confounding factors (e.g. exercise was performed in a group setting, or the behaviour of the exercise leader or the selection of music was manipulated). The reference lists of the articles that were retained were also scanned for possible leads and all seemingly relevant articles were retrieved and read.

The 33 studies that were retained are summarized in table I and figures 1 and 2. In most cases, self-selected intensity approximated or exceeded the minimum level of the range recommended by the ACSM.[20] Specifically, the ACSM recommends that physical activity be performed within a range of intensity that extends between a low of 40–50% of oxygen uptake reserve ($\dot{V}O_2R$) or heart rate reserve (HRR) or 64–70% of maximal heart rate (HR_{max}) and a high of 85% $\dot{V}O_2R$ or HRR or 94% HR_{max}. This finding is consistent with the results of a recent meta-analysis, according to which walking interventions (with an intensity of 50–85% HRR) resulted in a 9% increase in $\dot{V}O_{2max}$.[60]

For example, in a sample of 29 adult habitual walkers (mean age 35 years), Spelman et al.[88] found that their average walking intensity was 69.7% of HR_{max} and 51.5% $\dot{V}O_{2max}$. In a sample of 11 female recreational walkers (mean age

Table I. Studies examining self-selected intensity[a]

Study	Participant characteristics (no., sex, mean age and age range if given)	Instructions	Activity, duration	%HR_{max}[b] or %HRR	% $\dot{V}O_{2max}$	RPE	Speed (m/s)
Brooks et al.[61]	36 F, 39.9 y (35–45 y)	Activities: "at a pace you would normally do them at home"; walking: "what you perceive to be a moderate pace"	a: sweeping b: window cleaning c: vacuuming d: lawn mowing e: walking, each for 15 min	a: 62 (48–80) lab a: 68 (50–86) home b: 61 (46–87) lab b: 61 (44–82) home c: 57 (42–75) lab c: 62 (45–81) home d: 75 (57–91) lab d: 72 (49–93) home e: 61 (47–79) lab		a: 12 (9–15) a: 12 (9–15) b: 11 (7–15) b: 11 (8–14) c: 11 (7–14) c: 12 (8–14) d: 13 (8–16) d: 13 (8–17) e: 11 (7–13)	1.53 (walk)
Browning and Kram[62]	a: 10 F normal-weight b: 10 F obese, 26 y	"comfortable walking pace"	Walking, 6×70 m, outdoor sidewalk		a: 36 b: 51		a: 1.40 b: 1.47
Browning et al.[63]	a: 9 F Class II obese b: 10 M Class II obese c: 10 F normal-weight d: 10 M normal-weight 24.5 y	"comfortable walking pace"	Walking, 6×70 m, outdoor sidewalk		a: 50 b: 40 c: 36 d: 25		a: 1.41 b: 1.42 c: 1.47 d: 1.41
Dishman et al.[47]	23 M, 23 y (18–31 y), a: 12 low-active b: 11 high-active	"an intensity that you prefer", "high enough so that you would get a good workout", "not so high that exercising daily or every other day would be objectionable", "an intensity that feels appropriate for you"	Cycle ergometer, 20 min	a: ~74 at min 5; ~79 at min 20 b: ~74 at min 5; ~85 at min 20	a: ~60 at min 5; ~62 at min 20 b: ~52 at min 5; ~62 at min 20	a and b: 10.9 at min 5; 14.2 at min 20	
Ekkekakis et al.[64] (study III)	19 F, 15 M, 22 y	"free to adjust the speed to their liking"	Treadmill walking, 15 min	22 (HRR) at min 8		9.90 at min 8	1.20 at min 8
Ekkekakis et al.[64] (study IV)	19 F, 23 M, 20 y	"free to adjust the speed of the treadmill"	Treadmill walking, 10 min	20 (HRR) at min 10		9.60 at min 10	1.24 at min 10
Ekkekakis et al.[65] (study II)	15 F, 14 M, 56 y (35–78 y)	"walk at the same pace they usually select when walking for exercise"	Treadmill walking, 15 min	64 at min 7; 65 at min 15		11.31 at min 7; 11.83 at min 15	
Farrell et al.[66]	5 M, 1 F, 30.0 y, distance runners	"freely chosen pace", "self-selected or preferred"	Treadmill running, 30 min		75.3 (65–90)	~9.3 at min 5; ~11.7 at min 30	

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Table I. Contd

Study	Participant characteristics (no., sex, mean age and age range if given)	Instructions	Activity, duration	$\%HR_{max}$[b] or %HRR	$\% \dot{V}O_{2max}$	RPE	Speed (m/s)
Fitzsimons et al.[67]	a: 9 F, 20–23 y b: 9 F, 75–83 y	c: “slow” d: “fast” e: “comfortable” f: “brisk”	Walking, 2×150 m, indoor track		ac: 24.2 bc: 46.8 ad: 46.9 bd: 77.6 ae: 32.6 be: 55.8 af: 45.1 (38–49) bf: 67.2 (43–99)		ac: 1.01 bc: 0.79 ad: 1.75 bd: 1.42 ae: 1.37 be: 1.15 af: 1.68 bf: 1.37
Focht and Hausenblas[68]	15 F, 20.0 y	“determined the resistance and pedalling cadence”	Cycle ergometry, 20 min	63.5 (no difference between lab and gym environment)		12.1 at min 5; 13.6 at min 20 (gym > lab)	
Glass and Chvala[69]	12 M, 6 F 18–25 y	“choose preferred levels of exertion”	a: treadmill b: cycle ergometer c: stair-stepper 20 min	a: 74.8 (HRR) b: 80.0 (HRR) c: 80.2 (HRR)	a: 43.3–63.3 b: 52.2–64.7 c: 47.2–61.2	a: 12.5 b: 12.6 c: 12.8	
Grant et al.[70]	6 M, 6 F, 68 y (54–78 y)	“walk at a brisk but comfortable pace”	Walking, indoor track, 18 min	60 (57 at min 3; 62 at min 18)	52 (47 at min 3; 55 at min 18)	10 (9 at min 3; 10 at min 18)	
Gunn et al.[71]	36 M, 40.0 y (35–45 y)	Activities: “at their usual intensity”; walking: “at what they perceived to be a moderate pace”	a: sweeping b: window cleaning c: vacuuming d: lawn mowing e: walking for 15 min each	a: 56 (40–78) lab a: 59 (43–83) home b: 55 (41–80) lab b: 54 (41–74) home c: 51 (35–69) lab c: 54 (39–71) home d: 65 (48–83) lab d: 59 (40–89) home e: 52 (34–66) lab		a: 12 (8–17) a: 12 (9–16) b: 12 (9–15) b: 11 (8–14) c: 11 (8–14) c: 11 (8–15) d: 12 (9–15) d: 12 (8–15) e: 11 (8–14)	1.44 (walk) (1.11–1.81)
Gunn et al.[72]	50 M, 60.6 y (55–65 y)	Activities: “at their normal pace”; walking: “at what they perceived to be a moderate pace”	a: sweeping b: window cleaning c: vacuuming d: lawn mowing e: walking for 13 min each	a: 56 (34–76) lab a: 63 (41–89) home b: 57 (39–75) lab b: 59 (41–86) home c: 55 (34–86) lab c: 60 (38–84) home d: 65 (44–83) lab d: 65 (43–91) home e: 55 (37–76) lab		a: 11 (7–15) a: 12 (7–17) b: 11 (7–15) b: 11 (7–15) c: 11 (7–16) c: 12 (7–16) d: 12 (9–15) d: 12 (8–15) e: 11 (7–15)	1.47 (walk) (1.11–1.78)

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Table I. Contd

Study	Participant characteristics (no., sex, mean age and age range if given)	Instructions	Activity, duration	$\%HR_{max}$[b] or %HRR	$\%\dot{V}O_{2max}$	RPE	Speed (m/s)
Hills et al.[73]	a: 30 obese, 47.8 y b: 20 non-obese, 36.9 y	c: freely selected pace consistent with "walking for pleasure" d: maximum pace the participant could maintain	Walking, level 2-km grass track	ac: 70 bc: 59 ad: 82 bd: 77		ac: ~11.1 bc: ~10.2 ad: ~14.1 bd: ~14.3	ac: 1.48 bc: 1.60 ad: 1.70 bd: 2.10
Larsson and Mattsson[74]	50 obese F, 20–65 y	"at a self-selected, comfortable speed"	Walking, 70 m indoor corridor, at least 4 min a: baseline b: 12 wk c: 64 wk		a: 59.3 (37–98) b: 47.6 (26–81) c: 51.8 (33–104)	a: Md 3/10 b: Md 2/10 c: Md 2/10	a: 1.19 b: 1.27 c: 1.25
Lind et al.[75]	23 inactive F, 43 y	"select the speed that they preferred"	Treadmill exercise, 20 min	74 at min 5; 83 at min 20 (61–118)	55 at min 5; 67 at min 20 (44–92)	10.96 at min 5; 13.78 at min 20 (11–18)	1.65
Malatesta et al.[76]	a: 5 F, 5 M, 62–70 y b: 9 F, 1 M, 79–87 y	Preferred speed averaged from increment from low, decrement from high	Treadmill walking, 5 min		a: 42.92 b: 60.75		a: 1.38 b: 1.16
Mattsson et al.[77]	57 F, obese, 44.1 y	"self-selected, comfortable speed"	Walking, 70 m indoor corridor, at least 4 min		56 (31–98)	Md 3/10 (0–7)	1.18 (0.98–1.38)
Michael and Eckardt[78]	a: 3 M runners (23, 30, 30 y) b: 3 M untrained students (22, 22, 22 y)	"felt as a hard workout, so that they would be tired after 15 min"	Treadmill running c: 0% grade d: 10% grade 15 min	~85, no differences between a and b			ac: 4.2–4.4 bc: 1.9–2.5 ad: 2.7–3.1 bd: 1.8–2.7
Michael and Hackett[79]	10 F high-school students (13–18 y)	"select a pace which would make them tired at the end"	a: treadmill b: cycle ergometer 15 min	a: ~88 b: ~83			
Murtagh et al.[80]	11 F, 40.2 y (22–58 y)	a: "observed" b: "brisk"	Walking, unobstructed pathway, 3 min	a: 67.3 b: 78.5	a: 59.0 b: 68.6	a: 11.5 b: 13.6	a: 1.60 b: 1.86
Nabetani and Tokunaga[81]	15 M, 23.4 y	"allowed participants to opt for self-selected intensity"	Treadmill running a: 10 min b: 15 min	~80			a: 2.365 b: 2.448
Parfitt et al.[82]	12 M (21.25 y); 14 F (19.93 y)	"select an intensity that you prefer, that can be sustained	Treadmill, 20 min		71 ("work rate increased over	9–12	

Continued next page

Table I. Contd

Study	Participant characteristics (no., sex, mean age and age range if given)	Instructions	Activity, duration	%HR_{max}[b] or %HRR	% $\dot{V}O_{2max}$	RPE	Speed (m/s)
		for 20 min and that you would feel happy to do regularly"			the duration of the exercise")		
Parfitt et al.[83]	12 M, sedentary, 36.5 y	"select an intensity that you prefer, that can be sustained for 20 min and that you would feel happy to do regularly"	Treadmill, 20 min		54.1	9.75 at min 5, 13.33 at min 20	
Parise et al.[84]	117 F (70.0 y) 95 M (71.4 y)	"walk at their normal brisk walking pace"	Walking, level path outdoors, 0.5 mile	All >50, 97% of F and 84% of M >60 56% of F and 28% of M >75		10–12	M: 1.59 (1.14–2.02) F: 1.54 (0.97–1.94)
Pintar et al.[85]	60 F, 20.72 y (18–30 y), a: hi-fit/normal-wt b: hi-fit/over-wt c: lo-fit/normal-wt d: lo-fit/over-wt	"walking intensity that you prefer", "to get a good workout", "not so high that exercising daily or every other day would be objectionable", "intensity that feels appropriate"	Treadmill walking, 2.5% grade, 15 min	a: 64.09 b: 63.15 c: 67.60 d: 70.24	a: 40.59 b: 37.43 c: 54.40 d: 51.47	a: 9.60 b: 9.40 c: 10.33 d: 10.07	a: 1.56 b: 1.37 c: 1.43 d: 1.41
Quell et al.[86]	28 F (64 y), 114 M (63 y) cardiac rehab patients	"walk one mile as briskly as possible"	Walking, indoor track, 1 mile (F: 20: 12 min; M: 17: 48 min)	F: 85 M: 79		F: 13.4 M: 12.0	F: 1.29 (0.98–2.00) M: 1.47 (0.98–2.00)
Rose and Parfitt[87]	19 F, sedentary, 39.37 y (22–55 y)	"select an intensity that you prefer, that can be sustained for 20 min and that you would feel happy to do regularly"	Treadmill, 20 min	62.40 at min 5 68.67 at min 10 69.30 at min 15 72.21 at min 20	60.20 (31.39–75.63)	10.79 11.53 11.68 12.05	
Spelman et al.[88]	22 F, 7 M, 34.9 y (22–58 y)	Determined based on unobtrusive observation at usual walking route	Walking outdoors, then level treadmill walking, 8 min	69.7 (50.9–89.3)	51.5 (35.5–79.1)	10.9 (6–13)	1.78 (1.35–2.36)
Szabo[89] (study II)	32 F, 20.3 y	"set a pace at which she feels like exercising on that day"	Treadmill running or jogging (walking not permitted), 20 min	71 (HRR), range of 67 (from ~43 to ~110)			

Continued next page

Table I. Contd

Study	Participant characteristics (no., sex, mean age and age range if given)	Instructions	Activity, duration	%HR_{max}^b^ or %HRR	% $\dot{V}O_{2max}$	RPE	Speed (m/s)
Vazou-Ekkekakis and Ekkekakis[90]	19 F, 20.63 y (19–28 y)	"able to set the initial speed and to modify the speed to their liking every 5 min"	Treadmill exercise, 30 min	67.03		10.21	
Withers et al.[91]	50 F, 55–65 y	Activities: "the pace they normally do them at home", walking: "what they perceived to be a moderate pace"	a: sweeping b: vacuuming c: window cleaning d: lawn mowing e: walking	a: 66 (48–81) lab a: 74 (55–88) home b: 62 (45–76) lab b: 71 (47–89) home c: 67 (50–82) lab c: 70 (51–86) home d: 78 (59–93) lab d: 78 (59–95) home e: 65 (46–82) lab		a: 12 (8–16) a: 12 (9–17) b: 11 (8–15) b: 12 (7–17) c: 12 (8–16) c: 12 (8–15) d: 13 (8–17) d: 13 (9–17) e: 11 (8–15)	1.47 (walk)

a Numbers in parentheses show range values.

b HR_{max} unless HRR is specified.

c Percent signs have been omitted for simplicity.

F = female; **hi-fit** = high level of cardiorespiratory fitness; **HRR** = heart rate reserve; **lab** = laboratory; **lo-fit** = low level of cardiorespiratory fitness; **M** = male; **Md** = median; **RPE** = rating of perceived exertion; **wt** = weight.

40 years), Murtagh et al.[80] found that their average walking intensity was 67.3% HR_{max} and 59.0% $\dot{V}O_{2max}$. In a sample of 23 sedentary women (mean age 43 years), Lind et al.[75] found that self-selected walking intensity gradually increased from 74% HR_{max} or 55% $\dot{V}O_{2max}$ at minute 5 to 83% HR_{max} or 67% $\dot{V}O_{2max}$ at minute 20. In a sample of 12 low-active and 11 high-active male students (mean age 23 years), Dishman et al.[47] found that the average self-selected intensity on a cycle ergometer for both groups was approximately 62% $\dot{V}O_{2max}$ at the end of a 20-minute bout. In a sample of 60 college-age women (average age 21 years), Pintar et al.[85] found that self-selected intensity of treadmill walking during a 15-minute bout was 41%, 37%, 51% and 54% $\dot{V}O_{2max}$ and 64%, 63%, 70% and 68% HR_{max} in high-fitness normal-weight, high-fitness overweight, low-fitness overweight and low-fitness normal-weight subgroups, respectively.

The age of the participants and, importantly, the instructions given to participants, influenced the results. Participants who were younger (in their twenties) and non-obese, if given instructions that did not allude to purposeful *exercise* (e.g. they were instructed to walk 'slowly,' or at a 'comfortable' or 'moderate' pace, or that they were to 'walk for pleasure,' or that they were 'free to select' their speed but the experiment took place in a laboratory), they chose intensities that were below the lower limit recommended by the ACSM.[61-64,67,73] In some of these cases, the duration of the activity was also very short (i.e. 300–420 m), since the protocols were not intended to simulate a bout of exercise but rather to establish the typical walking speed for a particular population.[62,63,67] On the other hand, when young and non-obese participants were given instructions that referred to exercise or 'working out' or they were told that they were 'free to select' their intensity but the experiment took place in a gymnasium, the average self-selected intensities were within the recommended range.[47,68,69,85,90] Similarly, when men aged 35–45 or 55–65 years or women aged 35–45 years were asked to perform household activities at their 'usual' pace, the intensity tended to be below 64% HR_{max}.[61,71,72] On the other hand, for women

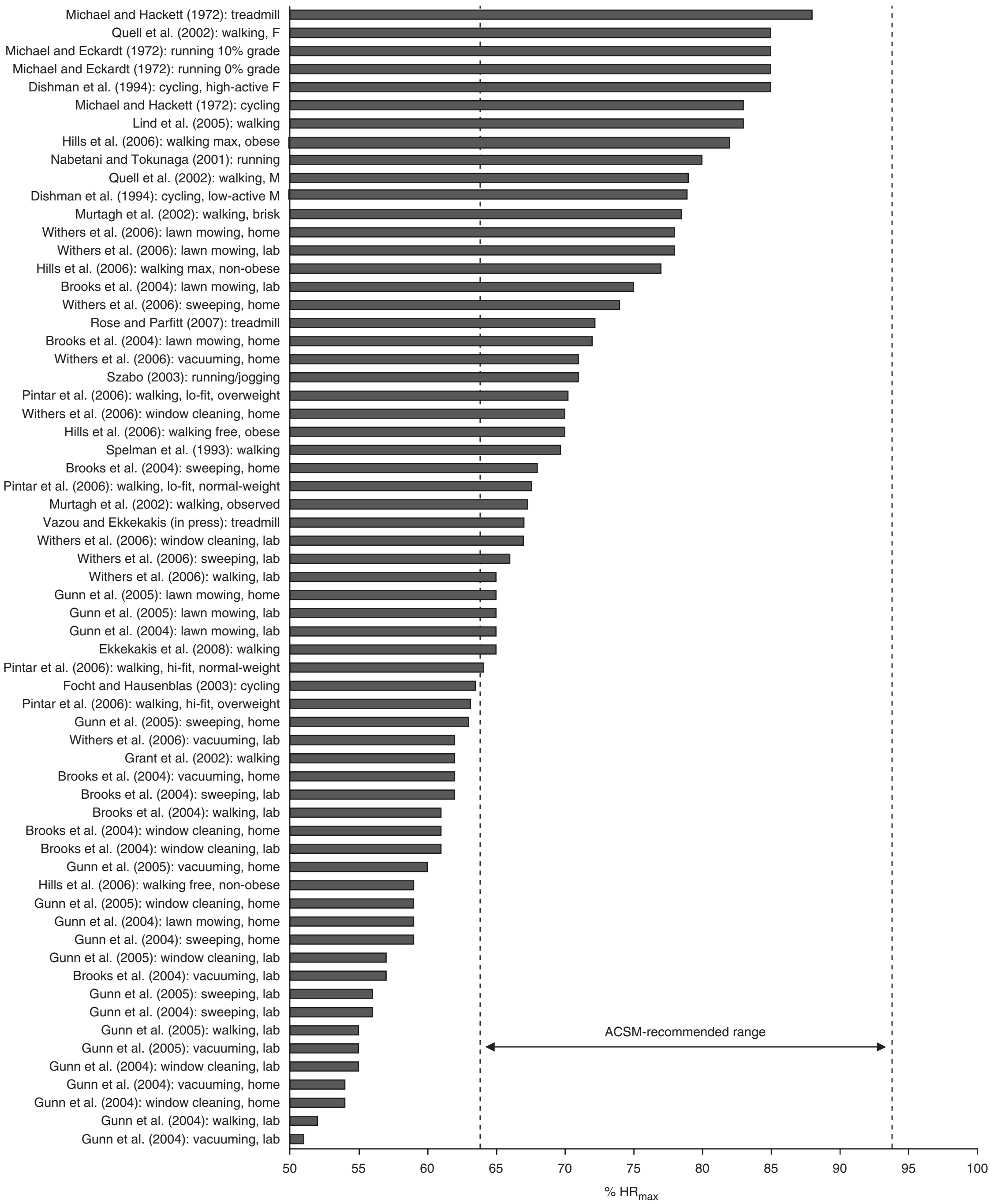

Fig. 1. Average percentages of maximal heart rate (%HR_{max}) recorded during physical activity performed at self-selected intensity in various studies and experimental conditions. The range of exercise intensity recommended by the American College of Sports Medicine (ACSM)[20] for the development and maintenance of cardiorespiratory fitness and health is also shown for comparison. **F** = female; **hi-fit** = high level of cardiorespiratory fitness; **lab** = laboratory; **lo-fit** = low level of cardiorespiratory fitness; **M** = male. See table I for citation numbers for studies.

aged 55–65 years, household activities (sweeping, vacuuming, window cleaning, lawn mowing and walking) typically raised heart rate to levels higher than 64% HR_{max}.[91] The exception to this pattern was the activity of lawn mowing (which involved pushing a 31 kg lawn mower), as it was consistently found to induce heart rates higher than 64% of age-predicted maximal regardless of the age of participants.

It should also be noted that, when participants were instructed, instead of selecting a 'preferred' or 'self-selected' intensity, to exercise at a level described as 'brisk' (as per the descriptor used in several physical activity recommendations) or 'fast,' the intensity was raised to levels well above the minimum of the recommended range. For example, the 11 women (22–58 years) studied by Murtagh et al.[80] reached 78.5% HR_{max} and 68.6% $\dot{V}O_{2max}$ when instructed to walk 'briskly'. When Hills et al.[73] instructed 30 obese adults to walk at the 'maximum pace they could maintain' for 2 km, they reached 82% HR_{max}. The nine elderly women (75–83 years) studied by Fitzsimons et al.[67] reached 67.2% $\dot{V}O_{2max}$ when they were instructed to walk 'briskly' and 77.6% $\dot{V}O_{2max}$ when they were instructed to walk 'fast'. The authors concluded that "in older adults, 'brisk' might elicit an exercise intensity that is unnecessarily high for physiological benefit and that might compromise safety and adherence" (p. 181). Intensities generally exceeding 80% HR_{max} were also observed in the studies in which the participants were instructed to jog or run, and walking was not offered as an option.[78,79,81,89]

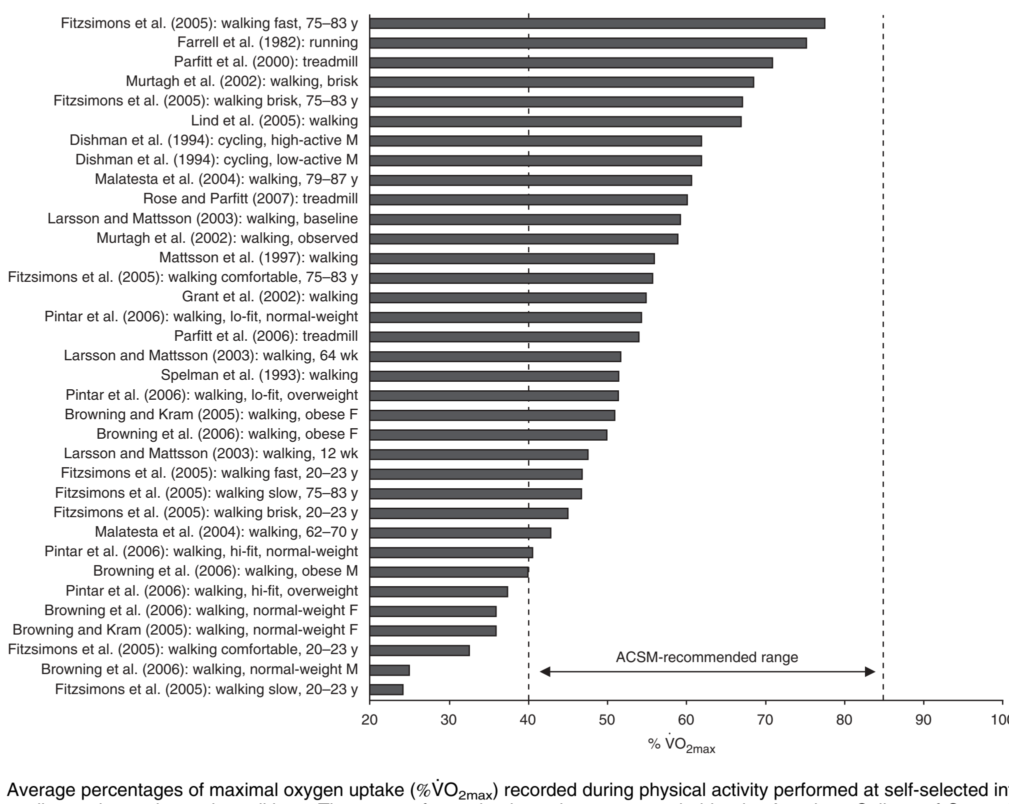

Fig. 2. Average percentages of maximal oxygen uptake (%$\dot{V}O_{2max}$) recorded during physical activity performed at self-selected intensity in various studies and experimental conditions. The range of exercise intensity recommended by the American College of Sports Medicine (ACSM)[20] for the development and maintenance of cardiorespiratory fitness and health is also shown for comparison (note, however, that these recommendations are based on oxygen uptake reserve, not $\dot{V}O_{2max}$). **F** = female; **hi-fit** = high level of cardiorespiratory fitness; **lo-fit** = low level of cardiorespiratory fitness; **M** = male. See table I for citation numbers for studies.

The review of the studies leads to the following additional observations. Firstly, one striking feature of these data is the degree of inter-individual variability in self-selected intensity. The range of individual data was presented in several studies and is summarized in table I. These ranges are very broad, with the lowest value typically being substantially below the lower boundary of the recommended range and the highest value approaching the higher boundary (i.e. 85% $\dot{V}O_{2max}$ or 94% HR_{max}). For example, in a sample of 29 adult habitual walkers (22 women, 7 men, mean age 35 years), Spelman et al.[88] found that the average walking intensity was 51.5% $\dot{V}O_{2max}$, with a range from 35.5% to 79.1%, and 69.7% HR_{max}, with a range from 56.0% to 89.3%. In a sample of 23 physically inactive women (mean age 43 years), Lind et al.[75] found that the average intensity at the final minute of the 20-minute bout was 67% $\dot{V}O_{2max}$, with a range from 44% to 92% and 83% HR_{max}, with a range from 61% to 118% of the highest value recorded during a previous graded test to volitional fatigue. In a sample of 57 obese women (mean age 44.1 years), Mattsson et al.[77] found that the average intensity was 56% $\dot{V}O_{2max}$, with a range from 31% to 98%.

Secondly, in most studies in which the participants could modify their intensity (either continuously or at distinct timepoints) over the course of the activity bout and physiological variables were tracked over time, the participants exhibited a tendency to gradually increase their intensity.[47,66,69,70,75,82,83,87] The reasons for this phenomenon are not clear. Some authors[47] have speculated that the participants apparently "employed an unsolicited warm-up strategy" (p. 787), and others have agreed.[82,83,87] Other authors have noted that the increase is not continuous until the end of the bout but, instead, there appears to be a stabilization after about 10–15 minutes.[75] These authors have speculated that this represents an exploratory strategy of searching for the level of intensity, beyond which any additional increase in intensity would bring about a decrease in pleasure.

Thirdly, Dishman et al.[47] were the first to notice that "[ratings of perceived exertion] at preferred intensities of exercise can uncouple from indicators of relative metabolic intensity typically linked with [ratings of perceived exertion] during grade- or load-incremented exercise or intensity-production tasks" (p. 787). The data summarized in table I provide some support to this observation. In several cases, although the self-selected intensity could be classified as 'moderate' (i.e. 64–76% HR_{max} or 40–59% HRR or $\dot{V}O_2R$) by ACSM[20] conventions (p. 4), ratings of perceived exertion were in the 9–11 range (on the 6–20 scale), suggesting that the intensity was perceived as 'very light' (i.e. <50% HR_{max} or <20% HRR or $\dot{V}O_2R$) or 'light' (i.e. 50–63% HR_{max} or 20–39% HRR or $\dot{V}O_2R$).[65,66,73,75,80,85,87,88,90] This is a potentially important observation, as it suggests that psychological factors unique to performing exercise at a self-selected intensity (i.e. perhaps the sense of autonomy and control) modify the theorized relationship between physiological variables and perceived exertion. If this is investigated in a systematic manner and found to be a reliable phenomenon, it would create an interesting opportunity for intervention efforts, since it suggests that individuals might be inclined to perform more intense activity when allowed to set their own intensity or, conversely, they might be inclined to tolerate lower levels of intensity when the intensity is imposed.

4. What is Known about the Determinants of Self-Selected Intensity?

The literature contains mainly two groups of studies concerned with the determinants of self-selected exercise intensity. In one group, the issue is approached from the perspective of bioenergetic optimization models. According to this view, the human gait (in the context of locomotion, not exercise) is regulated in a predictable fashion (hence the use of mathematical modelling), guided by the need to maximize the distance travelled while minimizing the metabolic cost.[92-95] In the second group of studies, the determinants of self-selected intensity (mainly in the context of exercise) are sought among common demographic and anthropometric characteristics, such as age, aerobic capacity, and body mass and composition.[47,76,78,79,96,97]

An alternative idea, which integrates elements of both approaches, is that the self-selection of intensity is regulated on the basis of affective responses (i.e. pleasure-displeasure) and that these, in turn, closely reflect homeostatic conditions. This notion stems from the seminal work of Cabanac[98-100] on the physiological role of pleasure. In one study, Cabanac and LeBlanc[101] created a conflict between muscular fatigue and ambient cold. The participants could choose (a) treadmill slopes varying from 0% to 24% while the ambient temperature was fixed and (b) ambient temperatures varying from 25°C to 5°C while the treadmill slope was fixed. The analysis showed that the choices made by participants were engineered to maintain an approximately steady core temperature and a heart rate that did not exceed 120 beats/min. These tacit 'strategies' were presumably aimed at balancing fatigue and cold and thus, according to Cabanac and LeBlanc,[101] maximizing pleasure or minimizing displeasure. The authors speculated that exceeding 120 beats/min would necessitate a substantial contribution of anaerobic metabolism and would thus result in displeasure. They noted that behavioural choices in their experiment involved "a compromise between the keen fatigue of anaerobic work and the threat of hypothermia" (p. R627). More specifically, "rather than passing above the anaerobic threshold, subjects accepted to let their temperature decrease" (p. R627).

In another series of studies, Cabanac[102,103] demonstrated that, when the speed of the treadmill was fixed and the participants could choose the slope or when the slope was fixed and the participants could choose the speed, the adjustments that the participants chose to make in speed and slope were reciprocal, resulting in the maintenance of an approximately constant amount of power and constant ratings of pleasure. Moreover, the individual choices could be predicted by the sum of the ratings of pleasure-displeasure that the participants experienced in their chests and lower limbs. Cabanac[103] speculated that "spontaneous behavior tends to be optimal in terms of physiological function" (p. 843) and that pleasure is the "common currency" people use in making behavioural choices in situations involving conflicting concerns.

It should be noted here that numerous studies in exercise physiology have established that the ventilatory and lactate thresholds coincide with the intensity most commonly selected by athletes during endurance events.[104-107] In this research, these thresholds have been found to be predictive of performance and, in fact, have typically been found to be stronger predictors of performance than maximal aerobic capacity.

Recent studies have built upon the groundbreaking ideas proposed by Cabanac, considering the affective responses of pleasure-displeasure as major determinants of behavioural choices and physiological thresholds as the 'turning points' beyond which pleasure during exercise begins to decline. Several studies in recent years, involving both incremental and steady-workload protocols, have provided evidence that ratings of affective valence (pleasure-displeasure) begin to decline at intensities that exceed the ventilatory or lactate threshold.[83,87,108-113]

Based on these findings, Lind et al.[75] proposed that the self-selection of intensity during exercise would be driven mainly by the desire to maintain a steady and positive affective state (or avoid a decline in the positivity of affect) and that, at least on average, this factor would cause most individuals to gravitate toward an intensity that approximates the ventilatory threshold (VT). Consistent with this postulate, they observed that, at the 15th and 20th minutes of a 20-minute bout of treadmill activity, the peaks of the distributions of self-selected intensity were centred precisely at 100% of the oxygen uptake associated with the VT (i.e. the average self-selected intensity did not differ significantly from the level of oxygen uptake associated with the VT). However, the distributions were broad, extending (at minute 20) from 60% to 160% of the oxygen uptake associated with the VT. In several of the studies summarized in table I, the authors noted that the average self-selected intensity was approximately coincident with the ventilatory or lactate threshold,[83] found that the VT was the major determinant of self-selected walking speed,[76] or speculated that this was probably the case.[67,85]

5. What is Known about the Basis of Individual Differences?

The large extent of the individual differences identified in the studies reviewed here is not a uniquely human characteristic. In their examination of the wheel-running patterns of six female albino rats, Premack and Schaeffer[114] found that one animal averaged 46 wheel revolutions per hour across multiple observation periods, whereas another averaged 515 revolutions per hour (an 11-fold difference). On one of the observation days, the difference was as large as 15 versus 556 revolutions per hour (a 37-fold difference). Similarly, in their observations of the physical activity patterns of 18 adult female rhesus monkeys using accelerometers, Sullivan et al.[115] recorded an 8-fold difference in daily activity counts between the most and the least active monkey. Importantly, the intraindividual activity patterns were consistent over time, with a 3-month test-retest correlation of 0.79.

Presumably, these large interindividual differences are indicative of the fact that, from an adaptational standpoint, the propensity for vigorous activity represents a trade-off between benefits and risks. If either a very low or a very high rate of activity were consistently linked to either a significant increase or a significant decrease in Darwinian fitness, variability would have been diminished (i.e. the beneficial trait would have spread, whereas the detrimental trait would have become extinct). On the one hand, having the tendency to move at higher intensity could provide an individual with more opportunities to maximize Darwinian fitness by covering more ground faster and potentially gaining access to more resources and mates. On the other hand, this tendency also carries a substantial cost by raising the daily metabolic budget and increasing the risk of suffering exhaustion, getting injured or falling victim to a predator.

Given the large interindividual differences but intraindividual consistency, it is not surprising that estimates of genetic heritability for spontaneous, voluntary or free-living physical activity in animals have been high. Of the various facets of activity (i.e. distance, duration, intensity), intensity has been found to exhibit the largest heritability indices. According to the study by Lightfoot et al.[116] across 13 strains of mice, between half and two-thirds of the variability in wheel-running velocity (i.e. self-selected exercise intensity) can be attributed to genetic factors (49–66% for males and 44–61% for females). Given these high heritability estimates, it is also not surprising that artificial selection experiments in both mice[117] and rats,[118] consisting of pairing male and female individuals with a high wheel-running propensity, have been very successful in producing offspring exhibiting much higher levels of daily activity than controls. Importantly, the offspring achieve these higher levels of activity primarily by running at higher average speeds (i.e. higher average intensity).

Commenting on the findings of the artificial-selection experiment in mice, Rezende et al.[119] noted that the mice from the selection lines never actually reach their maximal aerobic capacity while running voluntarily and, thus, their maximal aerobic or endurance capacity does not seem to be associated with or to limit their voluntary running. Instead, what drives the selected mice to run more, mainly by running faster, according to the authors, is a ''genetically higher motivation for wheel-running'' (p. 2447). Neurobiological investigations seeking to identify the brain regions that may underlie the tendency for selecting higher running intensities have pointed to the hippocampus and, more specifically, to the dentate gyrus, as a key regulator.[120-122]

Research in humans has examined the role of demographic and anthropometric characteristics, such as age, aerobic capacity, and body mass and composition. However, after taking into account their interdependencies,[96,97] these variables have been found to account for significant, albeit modest, parts of the variance in self-selected intensity in some studies[47,76] but not in others.[78,96]

From a psychological standpoint, the relatively few studies that have been conducted have focused on the role of personality traits and situational appraisals. In an early study, nine male participants exercised on a cycle ergometer against five levels of resistance (from 300 to 1500 kpm [2.94 to 14.71 kj]) for 1 minute each.[123] Extraversion was significantly and negatively correlated with ratings of perceived exertion at 900, 1200 and 1500 kpm (8.83, 11.77 and 14.71 kj) [–0.62, –0.69 and –0.71, respectively]. Furthermore, when the participants were subsequently asked which of these intensities they would have chosen if the exercise session was to last for 30 minutes, the selected level of intensity also showed a significant relationship (0.70) to extraversion.[123]

Hall et al.[124] followed a psychophysiological approach to investigate the variability in self-selected treadmill walking speed. Using electroencephalography, they computed an index of the asymmetric activation of the left and right frontal lobes. Greater left-versus-right frontal hemispheric asymmetry is considered an indication of an approach-oriented motivational tendency.[125,126] The index of asymmetric activation was found to be significantly related to self-selected walking speed after controlling for self-reported level of physical activity and resting heart rate.

More recently, Ekkekakis et al.[127] developed the Preference for and Tolerance of the Intensity of Exercise Questionnaire (PRETIE-Q). Preference for exercise intensity was defined as ''a predisposition to select a particular level of exercise intensity when given the opportunity (e.g. when engaging in self-selected or unsupervised exercise)'' and tolerance of exercise intensity was defined as ''a trait that influences one's ability to continue exercising at an imposed level of intensity when the activity becomes uncomfortable or unpleasant'' (p. 354). Both preference and tolerance were conceptualized as biologically rooted traits related to the modulation of somatosensory input. In a validation study involving a sample of sedentary middle-aged women, the Preference scale was found to account for 17–18% of the variance in physiologically defined self-selected exercise intensity (the percentage of oxygen uptake associated with the VT) beyond the variance accounted for by age, body mass index and cardiorespiratory fitness.[128] These percentages represented meaningful additions, given that the combination of the other three variables contributed 16–20% of the variance.

Among situational and task-specific variables, Ewart et al.[129] found that self-efficacy for exercise predicted the number of minutes that 40 male cardiac rehabilitation patients spent exercising above or below their target heart rate range. Low and medium self-efficacy was associated with a tendency to exercise below the minimum target heart rate, whereas high self-efficacy was associated with a tendency to exceed the maximum target heart rate. Other researchers have focused on social-environmental conditions, showing that being observed by onlookers[130,131] and exercising in a public exercise facility as opposed to the relative social isolation of a laboratory[68] tends to increase the level of self-selected exercise intensity.

6. Do People Select Whichever Intensity 'Feels Right' Anyway?

Although the ACSM guidelines[20] encourage the use of heart rate (primarily) and ratings of perceived exertion (secondarily) as ways of monitoring and regulating the intensity of exercise, a recent field survey showed that, in actuality, approximately nine out of ten adult women exercisers (86%) used neither method and instead regulated their intensity based on an intuitive sense of effort and exertion.[132] As many as 84% of the women, despite being regular exercisers, were not familiar with the Rating of Perceived Exertion scale and only 7% had a reasonably accurate estimate of their age-predicted maximal heart rate. Based on self-reported 'typical' levels of heart rate (77.2% HR_{max}) and perceived exertion (13.9 on the 6–20 scale), the authors speculated that ''subjects in this study appeared to exercise at an intensity that was just below their ventilatory or lactate thresholds'' (p. 448). Since the respondents reported performing continuous exercise for about 45 minutes per session, the authors reasoned that ''it is unlikely that exercise above threshold would be continued for this length of time'' (p. 448).

The findings of this survey underscore an important, albeit not frequently discussed, fact about studies investigating the effects of exercise interventions based on prescribed target heart rate ranges. When the participants are unsupervised, they apparently gravitate towards a 'preferred' level of intensity, an intensity that presumably 'feels right'. First, Pollock et al.,[133] commenting on a study that compared 80% and 90% HR_{max}, noted that "90% [HR_{max}] was too difficult for some men to maintain, while 80% was too slow" (p. 194) and, consequently, "many subjects in Group 1 [90% HR_{max}] had to be encouraged to keep their intensity up, while the converse was true for Group 2 [80% HR_{max}]" (p. 196). It should be noted, however, that the generalizability of the findings of Pollack et al.'s early study is limited, as it involved samples of prison inmates.

Nevertheless, the same finding re-emerged in subsequent studies. Based on their year-long study of previously sedentary adults (aged 50–65 years), King et al.[134] noted that "subjects performing higher-intensity training [i.e. 73–88% HR_{max}] tended to exercise at the low end of their prescribed range," whereas "subjects in the lower-intensity exercise training condition [i.e. 60–73% HR_{max}] tended to exercise at the high end of their prescribed heart rate range" (p. 1541). As a result, the two high-intensity conditions reported average ratings of perceived exertion of 13.3 and 13.1, whereas the corresponding number for the low-intensity condition was 11.7 – a difference of just ~1.5 unit on the 6–20 scale.

Also along similar lines, Cox et al.[54] found that participants assigned to a moderate-intensity group completed more sessions above the target heart rate range during their 18-month study, whereas those assigned to a vigorous-intensity group completed more sessions below the target heart rate range. Finally, Jakicic et al.[135] found that the ratings of perceived exertion recorded by two moderate-intensity groups, which were supposed to be between 10 and 12 (on the 6–20 scale), were 12.0 and 12.1 during the last 6 months of their 12-month intervention, whereas the ratings of two vigorous-intensity groups, which were supposed to be between 13 and 15, were both 13.3. In other words, as had been observed previously by others, there was a tendency for participants in the lower-intensity group to exercise at the high end of their prescribed range and a tendency for the participants in the higher-intensity group to exercise at the low end of their prescribed range. These findings suggest that, regardless of what prescription they are given, most individuals will probably regulate the intensity of their efforts on the basis of intuition, presumably driven mainly by their tendency to maximize pleasure and/or minimize displeasure.

7. What are the Psychological Effects of Imposing an Exercise Intensity?

Relatively few studies have directly compared the impact of self-selected and prescribed intensity on psychological responses such as mood, affect or enjoyment. Although earlier results were inconsistent, more recent investigations have started to shed light on the issue. Three of the earlier studies showed that exercise performed at an imposed intensity produced affective changes that were not significantly different from those elicited by self-paced activities. Firstly, Farrell et al.[66] had six experienced distance runners (five men, one woman, age 30 years) run for 30 minutes at 60% or 80% $\dot{V}O_{2max}$ or at a self-selected pace. On average, the self-paced run was performed at 75.3% $\dot{V}O_{2max}$. However, there was great interindividual variability, with one participant selecting to run at 65% $\dot{V}O_{2max}$ and showing no increase in blood lactate accumulation, and another selecting 90% $\dot{V}O_{2max}$ and accumulating 7.79 mmol/L of lactate. Although the changes in Total Mood Disturbance scores (obtained with the Profile of Mood States[136]) from 15 minutes before to 5–10 minutes after the runs did not differ significantly between the three conditions due to the highly variable responses and the small sample size, it is worth pointing out that the 60% and 80% $\dot{V}O_{2max}$ conditions led to a 15- and 16-unit improvement, respectively, whereas the self-paced run resulted in a 4-unit decline.

Secondly, Parfitt et al.[82] studied 12 men (age 21 years) and 14 women (age 20 years) who exercised on a treadmill for 20 minutes either at 65% $\dot{V}O_{2max}$ or a self-selected intensity (averaging

71% $\dot{V}O_{2max}$, with a gradual increase during the bout). The intensity manipulation had no effect on scores on the Subjective Exercise Experiences Scale[137] obtained before, every 5 minutes during and after the 20-minute bouts.

Thirdly, Focht and Hausenblas[68] divided a group of 30 young women (age 20 years) with high levels of social physique anxiety into two equal-sized groups, one assigned to self-selected (63.5% of age-predicted maximal heart rate) and the other to imposed-intensity (70–80% of age-predicted maximal heart rate, averaging 78.3%) stationary cycling for 20 minutes. They found no differences as a result of this intensity manipulation on state anxiety.

A problem with these studies is that the imposed levels of intensity (60%, 65%, 70–80%) were selected without a proposed basis for anticipating whether the self-selected intensity would be lower or higher than these levels. Thus, for some participants, the imposed intensity that was used for comparison was presumably above and for others below their self-selected level. This situation made it difficult to decipher whether any differences in the dependent variables were due to the independent variable (i.e. self-selected or imposed intensity) or due to the confounding effect of the level of intensity.

Parfitt et al.[83] conducted a study designed to address this problem. They theorized that individuals would select an intensity that would permit them to maintain a physiological steady state, as well as a steady and positive affective state. Thus, they compared the effects of 20-minute exercise bouts performed at an intensity corresponding to 2 mmol/L of blood lactate accumulation (39.8% $\dot{V}O_{2max}$), 4 mmol/L of lactate (72.6% $\dot{V}O_{2max}$), or at a self-selected pace (54.1% $\dot{V}O_{2max}$) among 12 sedentary men (age 36.5 years; $\dot{V}O_{2max}$ 34.1 mL/kg/min). A 4 mmol/L concentration of lactate was chosen as a hypothesized 'turning point', beyond which participants would be unable to maintain a physiological steady state as well as a steady and positive affective state. Parfitt et al.[83] found that blood lactate concentration did not change over time and did not differ between the 2 mmol/L lactate condition and the self-paced condition. In both conditions, lactate was significantly lower than the 4 mmol/L lactate condition, during which there was a significant increase over time (culminating at 7.17 mmol/L), suggesting an inability to maintain steady state. Also consistent with their expectations, self-ratings of pleasure-displeasure on the Feeling Scale[138] remained stable and positive during exercise at 2 mmol/L lactate and at self-selected intensity but declined significantly and eventually became negative during the bout at 4 mmol/L of lactate.

Rose and Parfitt[87] conducted a similar study with 19 sedentary women (age 39.37 years; $\dot{V}O_{2max}$ 36.1 mL/kg/min). The participants completed four 20-minute bouts on the treadmill: (i) a bout below lactate threshold (67.04% $\dot{V}O_{2max}$); (ii) a bout at lactate threshold (75.79% $\dot{V}O_{2max}$); (iii) a bout above lactate threshold (85.27% $\dot{V}O_{2max}$); and (iv) a bout at self-selected intensity (60.20% $\dot{V}O_{2max}$). Lactate levels during the self-selected condition (2.06 and 2.52 mmol/L at minute 10 and 20, respectively) did not differ from those during the condition below lactate threshold (1.56 and 1.36 mmol/L) or at lactate threshold (2.76 and 2.62 mmol/L). On the other hand, lactate levels during the condition above lactate threshold (5.72 and 6.04 mmol/L) were significantly higher than those during the other three conditions. Self-ratings of pleasure-displeasure on the Feeling Scale showed a significant decline during the condition above lactate threshold but remained stable and positive in the other three conditions. Exercise at a self-selected intensity led to more positive responses compared with exercise above and at lactate threshold and equally positive responses as those during the condition below lactate threshold.

Sheppard and Parfitt[139] extended this experimental paradigm to adolescents. The participants (11 boys and 11 girls, age 13.3 years) completed three 15-minute bouts on the cycle ergometer: (i) a bout at 80% of the power output associated with the VT (150.3 beats/min); (ii) a bout at 130% of the power output associated with the VT (182.0 beats/min); and (iii) a bout at a self-selected intensity (155.4 beats/min). Consistent with the previous studies in this series, self-ratings of pleasure-displeasure on the Feeling Scale showed a significant decline during the bout above the VT but remained positive and stable during the bouts below the VT and at the self-selected intensity (with no difference between the latter two conditions at any timepoint).

Lind et al.[140] designed a study that was also based on the assumption that, when allowed to self-select their exercise intensity, most individuals would choose a level that approximates their ventilatory (or lactate) threshold because this intensity would allow them to maintain a stable and positive affective state. By implication, then, if an imposed intensity exceeded the preferred level, even by a minor amount, most participants would be pushed to exercise above their threshold. Based on the substantial body of evidence that has accumulated during the past few years, however, supra-threshold intensities are accompanied by significant declines in pleasure.[83,87,108-113] Thus, Lind et al.[140] compared the affective responses of a sample of sedentary middle-aged women (age 43.68 years; $\dot{V}O_{2max}$ 22.98 mL/kg/min) when they self-selected their intensity during a 20-minute bout of treadmill exercise and when the speed was imposed and exceeded the self-selected level by just 10%. Consistent with expectations, the women self-selected an intensity that stabilized at a level not significantly different from their VT (98.07% of the oxygen uptake associated with the VT at minute 20). That intensity also did not exceed the conventional hallmark of blood lactate accumulation (i.e. 4.0 mmol/L), peaking at 3.14 mmol/L. It was, however, well within the range recommended by the ACSM[20] for the improvement and maintenance of cardiorespiratory fitness, reaching 84.17% HR_{max} at minute 20. On the other hand, when the treadmill speed was accelerated by just 10% (by 0.16 m/sec), oxygen uptake reached 115.40% of the level that corresponded to the VT, lactate exceeded the 4.0 mmol/L conventional marker (at 4.80 mmol/L), and heart rate approached the maximum of the recommended range (91.14% HR_{max}). In line with the hypothesis, self-ratings of pleasure-displeasure using the Feeling Scale remained positive and stable during the bout at self-selected intensity but showed a continuous and significant decline during the bout at imposed intensity.

Although the study by Lind et al.[140] demonstrated how fragile the balance can be between a bout of physical activity yielding a positive affective response and one that makes the participants feel significantly worse, its design could not decipher whether the affective decline was due to the increased intensity or due to the loss of perceived autonomy. To address this question, Vazou-Ekkekakis and Ekkekakis[90] designed a study based on the self-determination theory,[38] hypothesizing that the loss of perceived autonomy alone (i.e. even in the absence of a difference in intensity) would be sufficient to produce a less positive affective experience. In that study, 19 college-age women (age 20.63 years) completed two 30-minute bouts of treadmill exercise. During the first, they could self-select the treadmill speed (autonomous condition). During the second, the speed was set by the experimenter but, unbeknown to the participants, was identical to what the participants had self-selected (controlled condition). In line with other findings summarized in this review, the self-selected intensity was within the range recommended by the ACSM,[20] averaging 67.03% HR_{max}. The experimental manipulation was effective in lowering all three components of perceived autonomy (i.e. locus of causality, volition, and perceived choice). Furthermore, consistent with the hypothesis, following the controlled condition, the participants reported lower levels of interest/enjoyment and perceived choice (two components of intrinsic motivation), as well as attenuated pre-to-post increases in perceived energy, compared with the autonomous condition.

Interviews with participants conducted after exercise sessions performed at self-selected intensity also support the tenets of the self-determination theory.[38] For example, 11 of the 12 exercisers interviewed by Parfitt et al.[83] stated that they preferred the ‘self-selected’ condition because it gave them a sense of control (e.g. enabling one to exercise within one’s capabilities but also allowing one to select a higher intensity, if desired). Similarly, Rose and Parfitt[87] reported that participants after the session at self-selected intensity commented on feeling in control, believing that they were able to cope more easily, and being able to let their mind wander freely during exercise. On the other hand, some participants also expressed some concern about whether their selection of intensity was consistent with the expectations of the experimenters or whether they were being judged.

This point brings up the issue of perceived social pressure. It should be emphasized that an intensity level can be 'imposed' not only by a specific external agent (e.g. a personal trainer or a rehabilitation specialist) but also by the perceived social environment. As discussed earlier, when individuals are observed by others when they exercise, they exhibit a tendency (presumably driven by self-presentational concerns) to raise their intensity.[68,131] It is thus not surprising that studies investigating the level of exercise intensity achieved during sessions of group aerobics (a very popular form of exercise, particularly for women) have reported values near or even above the maximum of the recommended level. Clapp and Little[141] found that participants in sessions of low-impact, high-impact, or step aerobics averaged 76% $\dot{V}O_{2max}$, with some individuals exceeding 85% $\dot{V}O_{2max}$ and an estimated 30% working above their lactate threshold. Laukkanen et al.[142] found that the intensity peaked at 88–92% HR_{max} or 80–86% HRR. Parker et al.[143] similarly reported an intensity of 86.8% HRR. De Angelis et al.[144] found that the intensity peaked at 92.8% HR_{max}, 99.5% of the maximal VO_2 value derived from a graded test on a stationary bicycle, and 6.1 mmol/L of blood lactate. Swaine et al.[145] found that the intensity was 86% HR_{max} for beginners and 87% HR_{max} for habitual exercisers, which was, on average, 16.8 beats/min higher than the heart rate associated with the VT. Although these data suggest that the intensities reached during group aerobics exceed those that individuals would self-select if exercising on their own, the psychological impact of any such differences has not been evaluated empirically. It is conceivable that factors such as the independent influence of music or social dynamics on affect could moderate the effects of intensity.

In summary, the results of the studies discussed in this section and, in particular, the results of the studies conducted in recent years, show that: (i) when asked to self-select an exercise intensity most individuals tend to gravitate toward an intensity that approximates their ventilatory or lactate threshold; (ii) the self-selected intensities are typically within the range recommended by the ACSM;[20] and (iii) exercise intensities that exceed the self-selected level are associated with significant declines in self-rated pleasure. Apparently, the imposed intensity does not need to exceed the self-selected level by a large amount for pleasure to decline. Instead, the balance appears rather fragile, since, when self-selecting an intensity (at least in the presence of an investigator), most individuals raise their intensity up to the highest level that permits the maintenance of a positive affective steady-state. This implies that any additional 'push' will incur an affective decline (within a margin of tolerance, with some being unable to sustain even the smallest such 'push' and some requiring a substantial 'push' before reporting an affective decline). There is also preliminary evidence that the affective decline may be due to both the added intensity and the loss of perceived autonomy inherent in an imposed exercise prescription.

8. Running Wheels versus Treadmills: What has been Learned from the Animal Literature?

Although drawing analogies between animal and human research can be precarious, it is worth noting that a substantial literature has emerged comparing adaptations associated with exercise of self-selected (i.e. spontaneous wheel running) and imposed intensity (i.e. treadmill running) in animals, particularly rodents. In the case of wheel running, the animals can choose the frequency, duration, intensity and intermittency of their activity, whereas in the case of treadmill running these are determined by the experimenters, usually based on general norms for a particular species or strain. Several researchers have observed that the two exercise modalities are not equivalent. Although wheel running seems to be intrinsically rewarding and most animals perform it willingly, treadmill running reveals great inter-individual differences, with some animals refusing to run altogether. Consequently, tr\eadmill running can act as a stressor and, as such, it has been shown to have a negative impact on certain physiological adaptations. Thus, comparisons between wheel and treadmill running in animals represent an interesting model of human self-selected and imposed exercise intensity.

In the acute exercise paradigm, Yancey and Overton[146] reported that, despite similar intensity, the initiation of treadmill running produced a larger increase in heart rate and mean arterial pressure and a larger decrease in mesenteric blood flow (indicative of a stronger sympathetic activation and/or parasympathetic withdrawal) than wheel running. This finding has been assumed to have a common mechanistic basis as that of an increased cardiovascular and muscle blood flow response in *anticipation* of treadmill running after a period of treadmill training.[147] Interestingly, the higher the intensity of previous forced treadmill running, the larger the ensuant anticipatory response,[148] suggesting that the phenomenon reflected acquired fear.

More recently, Yanagita et al.[149] examined the activation of the hypothalamic pituitary adrenocortical (HPA) axis in response to 1 hour of running on a treadmill (using "softly prodding stimulation by a stick," as is common practice) or spontaneous wheel running. Importantly, the two conditions resulted in distances that were not significantly different (390.5 ± 43.4 and 343.8 ± 27.8 m for treadmill and wheel running, respectively), so any differences in stress responses could not be attributed to different exercise doses. It should also be noted that this intensity is considered low for the particular strain of rats (Wistar) and therefore not physically stressful in itself. Furthermore, controls included rats in cages with locked wheels and rats that received prodding (equal number to those who exercised on the treadmill, approximately 25–30 times per hour) but not running. The results showed that there was a significant increase in activated neurons containing corticotropin-releasing hormone in the paraventricular nucleus of the hypothalamus (i.e. the starting point in the HPA axis) only in the treadmill-exercised rats. The rats that exercised on running wheels showed no significant increase and were not different from the controls (i.e. those with the locked wheels or those who only received prodding). Perhaps due to the less stressful nature of (spontaneous) wheel running compared with (forced) treadmill running, it has been found to induce a longer-lasting increase[150] in brain neurotrophic factors, accompanied by more prominent plastic changes in the hippocampus,[151] a brain area essential for learning and memory.

In the chronic training paradigm, Noble et al.[152] reported that only treadmill running, not wheel running, for 8 weeks resulted in a significant elevation of the levels of myocardial heat shock protein 72 (also known as 'stress protein', as it is a marker of cellular stress not specific to heat), even though similar distances were covered in both running conditions. Moraska et al.[153] found that 8 weeks of forced treadmill running produced some positive adaptations (attenuation in bodyweight gain and an increase in soleus nitrate synthase, indicative of enhanced mitochondrial efficiency) plus an array of negative changes indicative of chronic stress (adrenal hypertrophy, decreased thymus weight, decreased serum corticosteroid binding globulin that could result in chronically elevated levels of active corticosterone, decreased lymphocyte proliferation, and decreased immunoglobulin response to antigen). In an experimental aging study, Narath et al.[154] reported that 10 of 32 rats in a treadmill-running group died of various causes over a period of 23 months (approximating the rats' average life expectancy) compared with 0 of 32 in a wheel-running group. The wheel-running group also had significantly lower bodyweight and body fat than the treadmill-running group.

9. A Note on Intermittent Activity

The present review focuses on self-selected levels of exercise intensity. However, all the studies that were available in the literature and formed the basis of the conclusions presented here involved continuous activity over the course of the bout, without intermittent periods of rest or active recovery. This, however, may have more to do with convention and common models of practice than individual preferences. Creatures driven by instinct rather than culturally imposed conventions, including animals in the field and human children during play, mainly opt for intermittent activity.

In mice selectively bred for high voluntary wheel running, Girard et al.[155] found that selection resulted in shorter and more frequent bouts (a more intermittent pattern of running). Although the average running speed that the animals chose was about half their maximal speed (i.e. 2.7 compared with 5.1 km/h), no mouse was observed to run continuously for more than 135 seconds, and the mean bout length was considerably shorter than 1 minute. In their efforts to understand the evolutionary significance of intermittent patterns of locomotion, researchers have explored the possible adaptational advantages of this behaviour.[156] One such advantage is a significant increase in the capacity to move over long distances.[157] For example, in crabs, fatigue occurred after 7.5 minutes and 135 m of continuous activity at 0.30 m/sec. However, using 2-minute runs (also at 0.30 m/sec) interspersed with 2-minute pauses, fatigue occurred after 87 minutes and 787 m. In an absolute sense, this represents a 5.8-fold increase in distance capacity. Even when the *average* speed was matched (i.e. crabs ran continuously at the submaximal speed of 0.15 m/sec), the crabs travelled a distance 2.2 times longer when moving intermittently. The authors calculated that, by running intermittently, the crabs needed to reach only 73% $\dot{V}O_{2max}$ to achieve a speed of locomotion that would require 84% $\dot{V}O_{2max}$ if they were moving continuously.[158] A number of physiological mechanisms could account for the enhanced distance capacity. Intermittent activity could increase the efficiency of oxidative enzymes, allow the resaturation of myoglobin and haemoglobin, allow the resynthesis of glycogen and high-energy phosphate stores, and facilitate the removal of metabolic byproducts, such as hydrogen ions and inorganic phosphates.[156,159]

One of the most extensive studies on the intensity of children's physical activity was conducted by Bailey et al.[160] In their study, eight boys and seven girls (aged 6–10 years) were observed for nine 4-hour periods each, covering the hours from 8:00am to 8:00pm. Every 3 seconds, trained observers recorded 42 different activities, 30 of which had been previously examined to determine their oxygen uptake requirements on a calibration sample of two boys and two girls. They found that the children engaged in activities of low intensity (13–24% $\dot{V}O_{2max}$) 77% of the time, activities of moderate intensity (25–45% VO_{2max}) 20% of the time, and activities of high intensity (46–91% $\dot{V}O_{2max}$) 3% of the time. The authors noted that the median duration of activity events of low and moderate intensity was 6 seconds, whereas events of high intensity lasted only 3 seconds (which was the minimal duration detectable by the observational recording method). Nearly all (95%) high-intensity activity events lasted fewer than 15 seconds and just 0.1% (10 of 6672) lasted more than 1 minute. The longest bout of high-intensity activity observed during the 384 hours of observations was 4 minutes 27 seconds. Intervals interspersed between high-intensity activity events were highly variable, ranging from 3 seconds to 21 minutes 15 seconds, with a median interval length of 18 seconds. The majority (75%) of intervals lasted ≤54 seconds and nearly all (95%) lasted <4 minutes 15 seconds. Bailey et al.[160] also noted that during moderate-intensity activity, no more than 5% of the time was spent above the estimated VT, with the longest spurt not exceeding 6 seconds. During high-intensity activity, only 26.5% of the time was spent above the estimated VT, with the longest spurt not exceeding 24 seconds.

These data raise the possibility that an intermittent pattern of physical activity might be more 'natural' than the now-prevalent model of continuous physical activity. If so, this would have implications for the way the 'self-selection' of exercise intensity is conceptualized and operationalized. Only allowing participants to select their level of intensity but not allowing them to select the pattern (i.e. possibly alternating between periods of activity and rest or active recovery) is potentially restricting and might limit their sense of perceived autonomy.

This point may be particularly relevant to participants with conditions such as obesity[77] or intermittent claudication,[161] which limit their ability to exercise continuously for a prolonged period. For example, Donnelly et al.[162] found that only 3 of 17 obese women were able to walk continuously for 1 mile, and those who completed the walk took more than 20 minutes and reported being exhausted. Similarly, before an exercise intervention, patients with intermittent claudication could walk for only 2.9–3.3 minutes until the onset of pain and for 7.2–7.4 minutes until they experienced maximal (i.e. intolerable) pain.[163] Clearly, for participants in these categories, intermittent activity is the only realistic way to accumulate a healthful amount of physical activity while avoiding or minimizing displeasure, exhaustion, pain, injury or cardiovascular complications. Until now, no known studies have compared the affective responses to continuous and isocaloric intermittent bouts of activity among any group of non-athletic participants. This might be a fruitful avenue for future research.

10. Conclusions and Implications for the 'Prescription-versus-Preference' Debate

Having completed the review of the available evidence, we can now return to the debate between schools of thought within the exercise sciences advocating 'prescription' and those advocating 'preference'. To facilitate a resolution, it is useful, if not necessary, to accept the following principle as axiomatic: what we ultimately strive for as exercise scientists and practitioners with a public health focus is promoting a *lifelong* commitment to physical activity. The corollary of this principle is that, although the *acceleration* or *maximization* of the exercise-derived health or fitness benefits are important considerations, they cannot be considered as having precedence over the prime objective (i.e. the development of a lifelong commitment to physical activity). If the *acceleration* or *maximization* of benefits endanger the prime objective (e.g. by reducing enjoyment or increasing pain), these considerations should be seen as of secondary importance.

An example of what happens if one strays from this principle is the popular notion of 'dieting'. A 'diet' has registered in public perception as a highly atypical and unpleasant deviation from normalcy, akin to a sacrifice (or a 'bitter pill'), which is to be tolerated strictly until the achievement of a short-term goal and be discontinued immediately thereafter. Setting aside the substantial health risks involved, the rates of weight re-gain, which often approach 100%, provide clear evidence of the futility and fallaciousness of this approach. Drastic measures can have quick and spectacular results but they make little sense if what one ultimately wants to accomplish is a stable and healthy behavioural change to last for a lifetime.

With this in mind, whether the dose of physical activity that is recommended to the public *maximizes* the rate or magnitude of the benefits is not the real issue. The issue, identified more than a quarter of a century ago,[57-59] is how to reach the best compromise between multiple considerations, namely: (i) identifying a range of physical activity options that are effective in improving fitness and health; (ii) ensuring that risk is minimized for as large a segment of the population as possible; and (iii) importantly, optimizing the conditions for a sustained (ideally, lifelong) behavioural change. To bridge the persistent chasm that has separated the prescription-based and preference-based approaches within the exercise sciences, all three of these considerations should be given equal weight in developing future physical activity recommendations.

What the data reviewed here demonstrate is that the issue of 'prescription-versus-preference' essentially presents a false 'either-or' dichotomy. It appears that, when most adults are allowed to self-select their exercise intensity (assuming that the activity is framed as 'exercise'), they choose a level within the range considered safe and effective for the development and maintenance of cardiorespiratory fitness. Particularly for individuals who are obese, formerly sedentary or older, this finding appears consistent. Therefore, the notion that individuals must be 'pushed' to achieve the 'target' level of exercise intensity is not supported by the data. This evidence should be examined in conjunction with findings that (a) self-selected levels of intensity appear to be associated with lower-than-expected levels of perceived exertion and (b) the imposition of intensity, particularly when it results in levels of intensity higher than the self-selected, appears to incur a psychological 'cost' (in the form of decreases in pleasure or interest/enjoyment and an attenuation of increases in perceived energy).

Studies that have examined the effects of home-based exercise or 'lifestyle' activity, both of which are unsupervised (even though a prescription or guidelines might have been provided), have consistently shown significant improvements in cardiorespiratory fitness and health outcomes of magnitudes generally not different from those of more traditional, supervised or structured, forms of activity. In the study by King et al.,[134] $\dot{V}O_{2max}$ improved equally (approximately 5%) in a group who performed centre-based exercise under supervision (73–88% HR_{max}) and two groups who exercised at home without supervision over a period of 12 months. As noted earlier, the two home-based groups were given different prescriptions (60–73% vs 73–88% HR_{max}) but, in actuality, converged toward intensities that differed minimally. Importantly, the two home-based groups showed significantly higher adherence over 12 months (75.1% and 78.7%, respectively) than the supervised centre-based group (52.6%). At 24 months, only the two home-based groups showed a significant increase in high-density lipoprotein cholesterol.[164]

Similarly, in the study by Andersen et al.,[165] obese women improved their $\dot{V}O_{2max}$ equally, regardless of whether they participated in a structured programme of step aerobics (18.8% improvement) or performed lifestyle physical activity (16.2% improvement) over the initial 16 weeks. Interestingly, by week 68, the participants in the lifestyle group had experienced a significant further increase to 24.2%, whereas those in the step aerobics group had remained at 16.3% compared with baseline. Importantly, besides $\dot{V}O_{2max}$, the two groups lost similar amounts of bodyweight by week 16 (8.3 vs 7.9 kg for the step-aerobics and lifestyle group, respectively) but by week 68 the aerobic group had regained 1.60 kg, whereas the lifestyle group had regained only 0.08 kg. The significant reductions in total cholesterol, triglycerides, and low-density lipoprotein cholesterol were similar in both groups.

Finally, Dunn et al.[166] reported that, following 6 months of intensive intervention and 18 additional months of maintenance, participants experienced similar improvements in $\dot{V}O_{2max}$, regardless of whether they were randomized to a structured aerobic exercise group (50–85% $\dot{V}O_{2max}$, 20–60 minutes, 3–5 days per week) or a lifestyle physical activity group (advised to accumulate at least 30 minutes of moderate-intensity physical activity on most, preferably all, days of the week). The two groups also experienced similar significant decreases in the percentage of body fat and systolic and diastolic blood pressure.

Since most individuals evidently opt to exercise at intensities proximal to their ventilatory or lactate threshold, the significant improvements in $\dot{V}O_{2max}$ with unsupervised exercise or lifestyle physical activity interventions should not be surprising. These results are consistent with the findings of a meta-analysis showing that intensities corresponding to the ventilatory or lactate threshold suffice to improve cardiorespiratory fitness among sedentary participants, with a large effect size of 2.32.[167] In fact, studies involving previously sedentary adults have shown that intensities exceeding the ventilatory or lactate threshold yield fitness gains that are not different from those associated with intensities slightly below or at these thresholds.[168-170] Thus, it could be said that the 'pain' (i.e. displeasure or discomfort) of supra-threshold exercise confers no additional fitness 'gain'.

Collectively, these findings form the basis of a persuasive argument in support of promoting physical activity performed at self-selected, rather than 'prescribed' or imposed, intensities in public health settings. There is, however, an important caveat, which pertains to the issue of interindividual differences. For reasons that remain inadequately understood, individuals differ greatly in the levels of exercise intensity they select; consequently, some may choose intensities that are too low to be effective or too high to be safe. This fact creates an urgent need for a research agenda aimed at improving the current understanding of the factors underlying these differences. In applied settings, instead of dictating the 'appropriate' intensity to participants, practitioners should redirect their efforts towards identifying individuals predisposed to select intensities that are too low or too high and providing consultation aimed at improving their self-monitoring and self-regulatory skills. Interventions based on the principles of biofeedback could be useful.[171] Even minimal learning interventions designed to improve self-monitoring accuracy (by providing feedback on discrepancies between perceived and actual physiological strain) have been found to be effective.[172-174] However, given the significant voids in the current understanding of the factors that predispose individuals to select intensities that are too low or too high, appropriate standardized protocols for screening for such tendencies and effective methods for helping individuals enhance their self-monitoring and self-regulatory skills are also lacking. These should be considered high-priority goals for future research.

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