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What intensity of physical activity do previously sedentary middle-aged women select? Evidence of a coherent pattern from physiological, perceptual, and affective markers

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Abstract

Background. The intensity of physical activity has been found to be inversely related to adherence, thus contributing to the problem of physical inactivity. Although most physical activity is unsupervised and participants, therefore, self-select the intensity, very little is known about the level of intensity that they select. We hypothesized that participants would select, on average, an intensity proximal to the level of transition from aerobic to anaerobic metabolism.

Methods. Twenty-three middle-aged, formerly sedentary women participated in (a) an incremental treadmill test to determine their maximal aerobic capacity and gas exchange ventilatory threshold, an index of the aerobic–anaerobic transition, and (b) a 20-min bout of treadmill exercise during which they were allowed to select the speed.

Results. On average, but with considerable interindividual variability, the women selected an intensity that, in terms of treadmill speed, heart rate, oxygen uptake, and perceived exertion was no different from the intensity corresponding to their gas exchange ventilatory threshold. Moreover, affective valence remained positive and stable.

Conclusions. On average, middle-aged, formerly sedentary women selected an intensity that is considered physiologically effective and reported that it did not feel hard or unpleasant. Future research should examine the sources of interindividual variability and the consequences of exercising at an intensity that exceeds one's preferred level.

Introduction

The low rates of participation in physical activity continue to be a public health concern of the highest priority in the United States and other industrialized countries. Despite the proliferation and wide dissemination of information about the health benefits of regular physical activity, the 1998–1999 review of the Healthy People 2000 program concluded that, over the past 15 years, "the proportion of the population reporting physical activity has remained essentially un-

changed, and progress is very limited" [88]. It is estimated that approximately two thirds of adults in the United States do not meet the current recommendation of at least 30 min of moderate physical activity on 5–7 days per week [51].

The problem of physical inactivity is the result of two associated problems, namely, the low rate of initial engagement and the high rate of dropout. Of the two, much more research attention has been devoted to the former than the latter, despite the fact that the problem of dropout, also known as the "revolving door phenomenon," is undeniably severe [30]. On average, based on clinical trials conducted in the last quarter century, the dropout rate is approximately 50% within the first few months of participation [31]. Although the existence of several theories from social psychology and other health behaviors has provided a

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starting block for investigating the process of initial adoption of physical activity, the processes leading to dropout continue to represent a largely unexplored area, a *terra incognita*. Moreover, guidelines for the prescription of physical activity continue to reflect primarily physiological considerations, namely, whether a given dose of physical activity (i.e., intensity, duration, frequency) will be effective at conferring health and fitness benefits [3]. Although it is generally acknowledged that the amount, particularly the intensity, of physical activity may impact pleasure and enjoyment and, ultimately, adherence, it is not yet possible to supplement these guidelines with specific suggestions that would ensure that the activity would be not only effective, but also pleasant or, at least, tolerable. The main reason is the lack of studies that have approached these issues from an integrative, psychobiological perspective. Consequently, the American College of Sports Medicine guidelines for exercise prescription simply state that "individual preferences for exercise must be considered to improve the likelihood that the individual will adhere to the exercise program" [3], without providing any specific suggestions.

A number of studies have demonstrated that there is an inverse relationship between the intensity of physical activity and adherence [21,38,61,75,79] and a meta-analysis of interventions for increasing physical activity found that interventions are considerably more effective when the intensity of physical activity is lower (i.e., 50% of maximal capacity or less) rather than higher [31]. Yet, despite the apparent importance of the intensity of physical activity for adherence, very little is presently known about the intensity that formerly sedentary individuals select once they make the decision to become physically active. Nevertheless, accumulating evidence suggests that this is an important problem as most individuals that lack recent physical activity experiences are generally inaccurate in self-monitoring and self-regulating the intensity of their efforts when the intensity is prescribed [34,55–57]. Several studies of women participating in aerobics, for example, have found that participants (some more than others) exceed their target heart rates and reach physiological intensities much higher than expected [20,26,59]. Therefore, it cannot be assumed that intensity prescriptions will be followed as intended. In fact, in longitudinal studies involving different levels of intensity, researchers observed a tendency for participants to diverge from the prescribed levels of intensity in favor of other, apparently preferred, levels [21,54].

In the few previous studies that examined the selection of physical activity intensity by nonathletic participants, the aim was to assess whether the selected intensity was within the recommended margins for the improvement and maintenance of cardiorespiratory fitness or health. The findings indicate that the selected intensities are generally within the limits recommended by the American College of Sports Medicine [3], namely, 55–65% to 90% of maximal heart rate (HRmax) and 40–50% to 85% of O_2 uptake reserve. However, the mean intensity varied considerably from study

to study, and individual intensity levels were found to exhibit large variability even within the same study. For example, in a sample of 29 adult habitual walkers (mean age 35 years), Spelman et al. [82] found that their mean walking intensity was 51.5% of maximal aerobic capacity ($\dot{V}O_2$max), with a range from 35.5% to 79.1%, and 69.7% of HRmax, with a range from 56.0% and 89.3%. In a sample of 11 female recreational walkers (mean age 40 years) of slightly lower fitness than those studied by Spelman et al., Murtagh et al. [67] found that their mean walking intensity was 59.0% $\dot{V}O_2$max and 67.3% HRmax. However, when these women were instructed to walk "briskly," as per the current physical activity recommendations, the values were significantly higher, namely, 68.6% $\dot{V}O_2$max and 78.5% HRmax. In a sample of 26 active college students (mean age 20 years), Parfitt et al. [71] found that the mean self-selected intensity on a treadmill was 71% $\dot{V}O_2$max. In a sample of 15 female college students (mean age 20 years), Focht and Hausenblas [43] found that the mean self-selected intensity on a cycle ergometer was 63.5% HRmax. In a sample of 12 low-active and 11 high-active male students (mean age 23 years), Dishman et al. [32] found that the mean self-selected intensity on a cycle ergometer for both groups was approximately 60% $\dot{V}O_2$max at the end of a 20-min bout.

The present study is based on the idea that, contrary to the apparent lack of consistency in previous findings, most individuals (within a reasonable margin of interindividual variability) will gravitate toward a specific and identifiable level of physical activity intensity that manifests itself across physiological, perceptual, and affective markers. The basic assumption that the selected level of intensity can be specified is derived from optimization models in the field of bioenergetics, which posit that the spontaneous selection of the speed and pattern of human gait is determined by the minimization of metabolic cost [2,8,33,58,93]. However, in the context of physical activity that is performed for the purpose of enhancing health and/or fitness, we propose that the selected intensity will approximate the point of transition from the level that can be maintained through aerobic metabolism to the level that requires anaerobic supplementation.

This hypothesis is based on several converging lines of evidence. First, there are important adaptational considerations. Specifically, although the reservoir of energy resources available to aerobic metabolism in the human body is vast (i.e., glycogen stores in muscle and liver, adipose tissue, and proteins from muscle and other depots throughout the body), totaling tens of thousands of kilojoules (kJ), the reservoir available for anaerobic metabolism, albeit replenishable at a finite rate, is minuscule by comparison (i.e., primarily the muscle phosphagen pool, and anaerobic glycolysis and glycogenolysis), totaling no more than a few dozen kJ [53,91]. This entails that an activity performed at an intensity that is high enough to rely on substantial anaerobic supplementation cannot be continued for long, necessitating a slow-down or cessation of

the activity. Theoretically, if the continuation of an activity whose demand for energy exceeded the rate of supply were possible in living organisms, the muscles would be irreparably damaged [35]. Adaptational considerations, therefore, suggest that an integrated system must have evolved to adapt the selection of physical activity intensity to metabolic constraints and, thus, maintain function within safe parameters.

Second, a series of recent studies have shown that significant declines in affective valence (i.e., decreases in pleasure or increases in displeasure) during physical activity are initiated specifically once the intensity exceeds the level of the aerobic–anaerobic transition [1,11,36,48]. In conjunction with the adaptational considerations outlined in the previous paragraph, this significant finding appears to indicate that evolution and natural selection might have shaped this particular affective response as a way of ensuring that the intensity of physical activity would not pose a threat to adaptation and survival. Consistent with this notion, several psychologists [4,47], physiologists [14], and neuroscientists [22,23,25] have proposed that affect is the main channel by which threats to homeostasis or departures from optimality manifest themselves in conscious awareness. This speculation is further supported by findings from exercise studies showing that the level of transition from aerobic to anaerobic metabolism is associated with consistent responses on Borg's Rating of Perceived Exertion (RPE) scale [13], generally in the 12–14 range, regardless of age, sex, or training status [27,50,76]. It is also interesting that, in studies in which participants were allowed to select their intensity, they chose intensities associated with RPE in the 12–14 range, regardless of whether the mode of activity was stair-stepping, cycling, or treadmill-running [32,46]. It is perhaps not coincidental that a rating of 13 corresponds to effort described as "somewhat hard," the first anchor that contains the word "hard" (the previous anchor, associated with a rating of 11, is "light").

Third, we posit that an individual's preference for a level of physical activity intensity depends on his or her affective response (i.e., pleasure or displeasure). In a seminal series of studies, Cabanac [15,16] 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 speculated that "spontaneous behavior tends to be optimal in terms of physiological function" [16] and that the guide for making such behavioral choices is pleasure. In this context, it is also noteworthy that, in a year-long clinical trial of previously sedentary adults (age 50–65 years), the experimenters noted a "preference for moderate-intensity exercise," as those who had been assigned to a higher intensity condition (73% to 88% of peak heart rate) "tended to exercise at the low end of their prescribed range," whereas those who had been assigned to the lower intensity condition (60% to 73% of peak heart rate) "tended to exercise at the high end of their prescribed heart rate range" [54]. The mean RPE value in the lower intensity group was 11.7 and those in two higher intensity groups were 13.1 and 13.3. Based on the similarity of these RPE values (i.e., 12–13) to those found to be associated with the level of the aerobic–anaerobic transition in previous research, it is reasonable to speculate that the participants spontaneously tended to select intensities proximal to the level of the aerobic–anaerobic transition.

Fourth, although the results have not always been consistent, several studies have found that endurance athletes tend to select a pace that approximates the level of the aerobic–anaerobic transition while running or cycling [60,74,92]. It is possible that nonathletic individuals, despite lacking the self-monitoring and self-regulatory experience of endurance athletes, intuitively make a similar choice, guided by their affective and exertional responses.

Advancing the present understanding of the mechanisms leading to dropout from physical activity is a top priority for public health. Factors related to the physical activity stimulus itself and, in particular, to the self-regulation of intensity may be significant contributors to dropout risk. Thus, the present study was designed as the first exploratory but hypothesis-driven research effort aimed at investigating the spontaneous selection of physical activity intensity by previously sedentary adults. The specific purpose of the study was to evaluate the hypothesis that sedentary, middle-aged women would choose to exercise at a predictable intensity. Specifically, it was expected that, following a period of approximately 10 min, during which the participants adjust their pace [16], the selected intensity would, on average, (a) approximate the level of transition from aerobic to anaerobic metabolism, (b) be associated with ratings of perceived exertion in the 12–14 range, and (c) be associated with stable, positive ratings of affective valence.

Methods

Participants

An initial sample of 50 women expressed interest in participating in the study and contacted the investigators, after having seen posters, having received an electronic mail message (sent to the faculty and staff of a large state university) or having been informed about the study through word of mouth. The purpose of the first telephone interview was to ascertain that the women satisfied the criteria for inclusion in the study. Specifically, (a) they responded to a

7-day physical activity recall interview [12] to ensure that they expended less than the recommended 837 kJ [72] or participated in less than 30 min of moderate physical activity per day on most days of the week [3,86], (b) they reported that they had not changed their physical activity habits in the past 12 months (and thus, based on the 7-day physical activity recall, they were sedentary), (c) they certified that they had a physical examination in the previous 12 months that revealed no contraindications to vigorous physical activity, (d) they gave all negative responses to all the questions of the Physical Activity Readiness Questionnaire [17], indicating that they were apparently healthy, (e) they had no history of cardiovascular, respiratory, musculoskeletal, or metabolic conditions, (f) they were not suffering from any injuries or other ailments at the time, and (g) they were nonsmokers. Following this initial screening, 27 women were scheduled for testing. Of these, however, three terminated the incremental treadmill test without reaching a true peak (see the Procedures section), and one did not return for a second session. These four women were not considered in further analyses, leaving a final sample of 23. Their demographic and anthropometric characteristics appear in Table 1. One of the participants was a Pacific Islander, and the rest were all Caucasian (according to the 2000 census, 88% of the residents of the local community are Caucasian). All were native English speakers. The participants received no monetary compensation but were given the results of their fitness assessment and an individualized physical activity prescription upon the completion of the study.

Measures

Heart rate was examined as an index of intensity, as it is the primary method of prescribing and monitoring the intensity of physical activity, according to the American College of Sports Medicine [3]. Heart rate was assessed with a heart rate monitor (Polar Electro Oy, Finland), consisting of a stretchable chest band and a radio transmitter interface to a computerized metabolic analysis system (see below). Validation studies have shown correlations between this method and electrocardiographically measured heart

rate typically in the 0.94 to 0.99 range and differences between 1 and 12 beats min^{-1} [62,80,85,89].

O_2 uptake was assessed with an open-circuit computerized spirometry system (model TrueMax 2400, ParvoMedics, Salt Lake City, UT). The system consists of a paramagnetic O_2 analyzer, an infrared CO_2 analyzer, and a pneumotachometer (model 3813, Hans Rudolph, Kansas City, MO) to measure ventilation. The system was calibrated for O_2 and CO_2 using a gas with certified concentrations of O_2 and CO_2 and for ventilation using a standard 15-stroke calibration procedure, using a 3-L syringe (model 5530, Hans Rudolph). A validation study of this system found that the differences compared to the gold-standard Douglas bag method were "so small as to be not physiologically significant" [5].

Blood lactate was examined as an additional index of intensity. The assessments were conducted using an Accutrend-Lactate analyzer and test strips (Roche Diagnostics, Indianapolis, IN). This analyzer uses enzymatic methods (lactate oxidase on the reagent strip converts lactate to pyruvate and molybdenum blue) and reflectance photometry (at 660 nm, measuring the molybdenum blue, which is proportional to the lactate concentration) to produce a result in 60 s. A series of validation studies have shown that the Accutrend-Lactate analyzer (formerly Accusport) has acceptable reliability, validity, and linearity [10,41,64,77]. In the present study, lactate was assessed by (a) first wiping one finger tip of the nondominant hand with an alcohol swab, (b) pricking the finger tip using a spring-loaded lancet device with a sterile lancet, (c) using a sterile heparinized capillary tube to draw a 25–30 μL sample of blood, (d) applying this sample to a lactate test strip (Roche Diagnostics) using an applicator, and (e) analyzing the sample immediately using the Accutrend-Lactate analyzer.

Perceived exertion, using Borg's RPE [13], was examined as an index of intensity, as it is considered by the American College of Sports Medicine as an "adjunct to monitoring heart rate" [3], "a valuable aid in prescribing exercise for individuals who have difficulty with heart rate palpation" [3], and "a guideline in setting the exercise intensity" [3]. The RPE is a 15-point single-item scale ranging from 6 to 20, with anchors ranging from "Very, very light" to "Very, very hard". The validity of the RPE is supported by extensive evidence [69]. Specifically, a recent meta-analysis showed that the RPE exhibits the following weighted mean validity coefficients with physiological indices of intensity: 0.62 for heart rate, 0.57 for blood lactate, 0.64 for percentage of maximal aerobic capacity, 0.63 for O_2 consumption, 0.61 for ventilation, and 0.72 for respiratory rate [18].

Affective valence (positivity–negativity or pleasure–displeasure) was examined because of previous evidence indicating the sensitivity of this index to the aerobic–anaerobic transition [1,11,36,48]. Affective valence was assessed by the Feeling Scale (FS) [49]. The FS is an 11-

Table 1
Demographic, anthropometric, and physiological characteristics of the participants ($N = 23$)

	M ± SD
Age (years)	43.43 ± 4.85
Body mass (kg)	78.13 ± 17.04
Height (m)	1.67 ± 0.06
Body mass index (m/kg^2)	28.03 ± 6.25
Est. % body fat (%)	27.42 ± 5.69
$\dot{V}O_2$peak (mL kg^{-1} min^{-1})	22.98 ± 5.69
HRpeak (beats min^{-1})	159.32 ± 24.08
%$\dot{V}O_2$peak at GET (%)	70.50 ± 10.73
%HRpeak at GET (%)	82.74 ± 11.59

point, single-item, bipolar rating scale commonly used for the assessment of affective responses during exercise. The scale ranges from −5 to +5. Anchors are provided at zero ("Neutral") and at all odd integers, ranging from "Very Good" (+5) to "Very Bad" (−). Hardy and Rejeski [49] have provided evidence of significant correlations between the FS and other self-report measures of pleasure.

Procedures

Participation in the study required two visits to the laboratory. The first session involved an incremental treadmill test to volitional exhaustion, to determine peak O_2 uptake ($\dot{V}O_2$peak), peak heart rate (HRpeak), and gas exchange ventilatory threshold (GET). The second session involved a bout of treadmill exercise at a self-selected pace.

Before starting the first session, all participants read and signed an informed consent form approved by the university's Institutional Review Board. Then, each participant was fitted with the heart rate monitor chest band, was weighed, and underwent a measurement of the thickness of three skin folds (thigh, tricep, suprailiac) for the estimation of body adiposity. Next, each participant was fitted with a nasal and mouth-breathing face mask made of silicone rubber (model 8920/30, Hans Rudolph) and equipped with an ultralow-resistance, T-shaped, two-way, nonrebreathing valve (model 2700, Hans Rudolph), which was, in turn, connected to the spirometry system via plastic tubing (35 mm in diameter). A gel sealant (model 7701, Hans Rudolph) was applied to the face mask to prevent leaks. According to the manufacturer, compared to the traditional mouthpiece and nose-clip design, the nasal and mouth-breathing mask design has the advantage of comfort by eliminating jaw fatigue, saliva buildup, dry mouth, and throat irritation. In addition, this design allows vocal communication between participant and experimenter. Given that the present study involved the assessment of perceptions of exertion and affective responses, the use of this type of mask was deemed necessary.

Two min of resting data were collected while the participant was standing on the belt of the treadmill (model L8, Landice, Randolph, NJ) to ensure the proper functioning of the components of the spirometry system. The incremental treadmill test began at a speed of 4.0 km h^{-1} and 0% grade for 2 min. Thereafter, the speed was increased by 0.64 km h^{-1} every second min (while maintaining the grade at 0%) until each participant reached the point of volitional exhaustion. For 3 of the 27 participants, the criteria for reaching maximal capacity (i.e., reaching age-predicted maximal heart rate, plateau in oxygen consumption with increasing workloads, and a respiratory exchange ratio greater than 1.1) were not satisfied, as these women terminated the test due to musculoskeletal complaints (e.g., knee pain, perceived weakness in the legs). As noted earlier, these three women were excluded from further analyses.

For the second session, the women were told that they were to engage in a 20-min bout of activity on the treadmill (without specifying walking or jogging), during which they would be able to select the speed that they preferred. After again being fitted with the heart rate monitor and face mask following the same procedures described above, each participant was allowed to warm up by walking for 5 min at 4.0 km h^{-1} and 0% grade. After the warmup, each participant set the speed that she preferred (0:00 min) and was allowed to make adjustments (faster or slower, but with the grade always fixed at 0%) every 5 min of the 20-min bout (min 5:00, 10:00, 15:00). Ratings on the RPE and FS scales were obtained at min 0:00, 4:45, 9:45, 14:45, and 19:45 by displaying a poster-size version of the scales and asking the participant to indicate her response either verbally or by pointing to a number. Immediately after completing the 20-min bout, the treadmill was stopped, the face mask was removed, and a droplet of blood was obtained for lactate analysis (following the procedure described previously). Following this interruption (lasting approximately 2 min), the treadmill was restarted, and the participant was allowed to cool down by walking for 5 min at 4.0 km h^{-1} and 0% grade. After a 20-min passive (seated) recovery and observation period, the participants were debriefed, thanked, and released.

Determination of the gas exchange ventilatory threshold

The individual GET was assessed, as it was considered an indirect, but noninvasive, index of the transition from aerobic to anaerobic metabolism. Studies using near-infrared spectroscopy to evaluate muscle oxygenation during exercise have shown that the systematic decrease in absorbency values coincides with the GET [7,9,65], suggesting that, even if there is no mechanistic connection between anaerobiosis in the muscle and GET, the two phenomena occur simultaneously or in close succession. The GET was determined by a computerized version of the three-method combined procedure proposed by Gaskill et al. [44]. Specifically, the following methods were used: (a) the V-slope (i.e., plotting CO_2 production over O_2 utilization and identifying a breakpoint in the slope of the relationship between these two variables), (b) the method of the ventilatory equivalents (i.e., plotting the ventilatory equivalents for O_2 ($\dot{V}_E/\dot{V}O_2$) and CO_2 ($\dot{V}_E/\dot{V}CO_2$) over time or over O_2 utilization and identifying the level of exercise intensity corresponding to the first rise in $\dot{V}_E/\dot{V}O_2$ that occurs without a concurrent rise in $\dot{V}_E/\dot{V}CO_2$, (c) the Excess CO_2 method (i.e., plotting Excess CO_2 over time or O_2 utilization and identifying the level of exercise intensity corresponding to an increase in Excess CO_2 from steady state). All data were converted to 20-s averages before analysis. A series of published algorithms using two-segment, piecewise regressions were used to identify the breakpoint in each of the aforementioned data relationships [6,19,28,52,70]. In each case, the solution was verified by

visual inspection after plotting regression lines through the pre- and post-breakpoint data segments. The GET was determined to occur at the point where at least two of the three methods converged or the point that resulted in the lowest mean square residual.

Reduction of physiological data

All indices of intensity were expressed as percentages of the peak values attained during the incremental treadmill test and of the levels corresponding to the GET. The highest 1-min average of O_2 uptake was designated $\dot{V}O_2$peak, and the highest 1-min average of HR was designated HRpeak. O_2 uptake, HR, and treadmill speed data collected during min 0, 5, 10, 15, and 20 of the 20-min self-selected intensity session were averaged, and these 1-min averages were converted to percentages of the peak values and those corresponding to the GET. Finally, the blood lactate concentration measured after the self-selected intensity session was expressed as a percentage of the value attained at the end of the incremental treadmill test.

Statistical analysis

The data for treadmill speed, HR, $\dot{V}O_2$, RPE, and FS were analyzed using repeated-measures one-way analyses of variance (ANOVAs) by time. Whenever the sphericity assumption was violated, the conservative Greenhouse-Geisser correction was applied to the degrees of freedom, and the adjusted degrees of freedom and probability levels are reported. Findings of significant variance were followed-up by pairwise comparison, using the Least Significant Difference (LSD) procedure, to protect against type I error rate inflation. The hypothesis that there would be no significant differences between the levels of treadmill speed, HR, $\dot{V}O_2$, RPE, and FS recorded during the bout at self-selected intensity and those corresponding to the GET was examined by paired-sample t tests.

Results

The lactate concentration at the end of the incremental treadmill test was ($M \pm SD$) 5.51 ± 2.49 mmol L^{-1}, whereas the value at the end of the bout at self-selected intensity was 3.34 ± 1.43 mmol L^{-1}. On average, this represented 67% of the concentration after the incremental test to volitional exhaustion, but the range of individual values was very large, from a low of 16% to a high of 145%.

The results for treadmill speed are shown in Fig. 1, panel a. A repeated-measures ANOVA by time (four levels: min 5, 10, 15, 20) on treadmill speed (as a percentage of peak) showed a significant effect of time, $F(1.55, 34.15) = 18.76$, $P < 0.001$, $\eta^2 = 0.46$. A trend analysis indicated a significant

quadratic pattern, $F(1, 22) = 5.57$, $P < 0.05$, $\eta^2 = 0.20$. The pairwise comparisons showed significant increases in speed from min 5 ($64\% \pm 7\%$) to min 10 ($69\% \pm 8\%$) and, finally, to min 15 ($73\% \pm 9\%$), but a stabilization from min 15 to min 20 ($74\% \pm 10\%$). At min 20, individual values ranged from a low of 54% to a high of 90% of peak.

The results for HR are shown in Fig. 1, panel b. A repeated-measures ANOVA by time (five levels: min 0, 5, 10, 15, 20) on HR (as a percentage of peak) showed a significant effect of time, $F(2.45, 51.45) = 15.70$, $P < 0.001$, $\eta^2 = 0.43$. A trend analysis indicated that, although the quadratic trend approached significance ($P = 0.08$), the only significant trend in the data was linear. The pairwise comparisons showed a significant initial increase from the end of the warmup ($67\% \pm 13\%$) to min 5 ($74\% \pm 13\%$), but no further point-to-point increases at min 10 ($78\% \pm 13\%$), min 15 ($79\% \pm 16\%$), or min 20 ($83\% \pm 13\%$). At min 20, individual values ranged from a low of 61% to a high of 118% of peak.

The results for $\dot{V}O_2$ are shown in Fig. 1, panel c. A repeated-measures ANOVA by time (five levels) on $\dot{V}O_2$ (as a percentage of peak) showed a significant effect of time, $F(1.85, 40.61) = 20.06$, $P < 0.001$, $\eta^2 = 0.48$. A trend analysis indicated a significant quadratic pattern, $F(1, 22) = 4.64$, $P < 0.05$, $\eta^2 = 0.17$. The pairwise comparisons showed significant increases in $\dot{V}O_2$ from the end of the warm-up ($47\% \pm 13\%$) to min 5 ($55\% \pm 10\%$), to min 10 ($60\% \pm 11\%$), and to min 15 ($64\% \pm 13\%$), but a stabilization from min 15 to min 20 ($67\% \pm 14\%$). At min 20, individual values ranged from a low of 44% to a high of 92% of peak.

The results for RPE are shown in Fig. 1, panel d. A repeated-measures ANOVA by time (five levels) on RPE showed a significant effect of time, $F(1.76, 38.65) = 66.30$, $P < 0.001$, $\eta^2 = 0.75$. A trend analysis indicated a significant quadratic pattern, $F(1, 22) = 12.06$, $P < 0.01$, $\eta^2 = 0.35$. The pairwise comparisons showed that RPE increased significantly across all time points, from the end of the warm-up (8.87 ± 1.77), to min 5 (10.96 ± 1.30), to min 10 (11.96 ± 1.36), to min 15 (13.09 ± 1.41), and, finally, to min 20 (13.78 ± 1.95). At min 20, individual values ranged from a low of 11 ("light") to a high of 18 (between "very hard" and "extremely hard").

The results for FS are shown in Fig. 1, panel e. A repeated-measures ANOVA by time (five levels) on FS showed no significant effect of time, $F(1.76, 38.69) = 0.72$, $P = 0.48$, $\eta^2 = 0.03$. FS remained stable throughout the bout at self-selected intensity, from the end of the warm-up (2.17 ± 1.23), to min 5 (2.22 ± 1.09), to min 10 (2.30 ± 1.11), to min 15 (2.39 ± 0.99), and, finally, to min 20 (2.48 ± 1.16). At min 20, individual values ranged from a low of 0 ("neutral") to a high of +4 (between "good" and "very good").

Expressed as a percentage of the treadmill speed at GET, the treadmill speed during the bout at self-selected intensity increased from $82\% \pm 12\%$ at min 5, to $89\% \pm 15\%$ at min
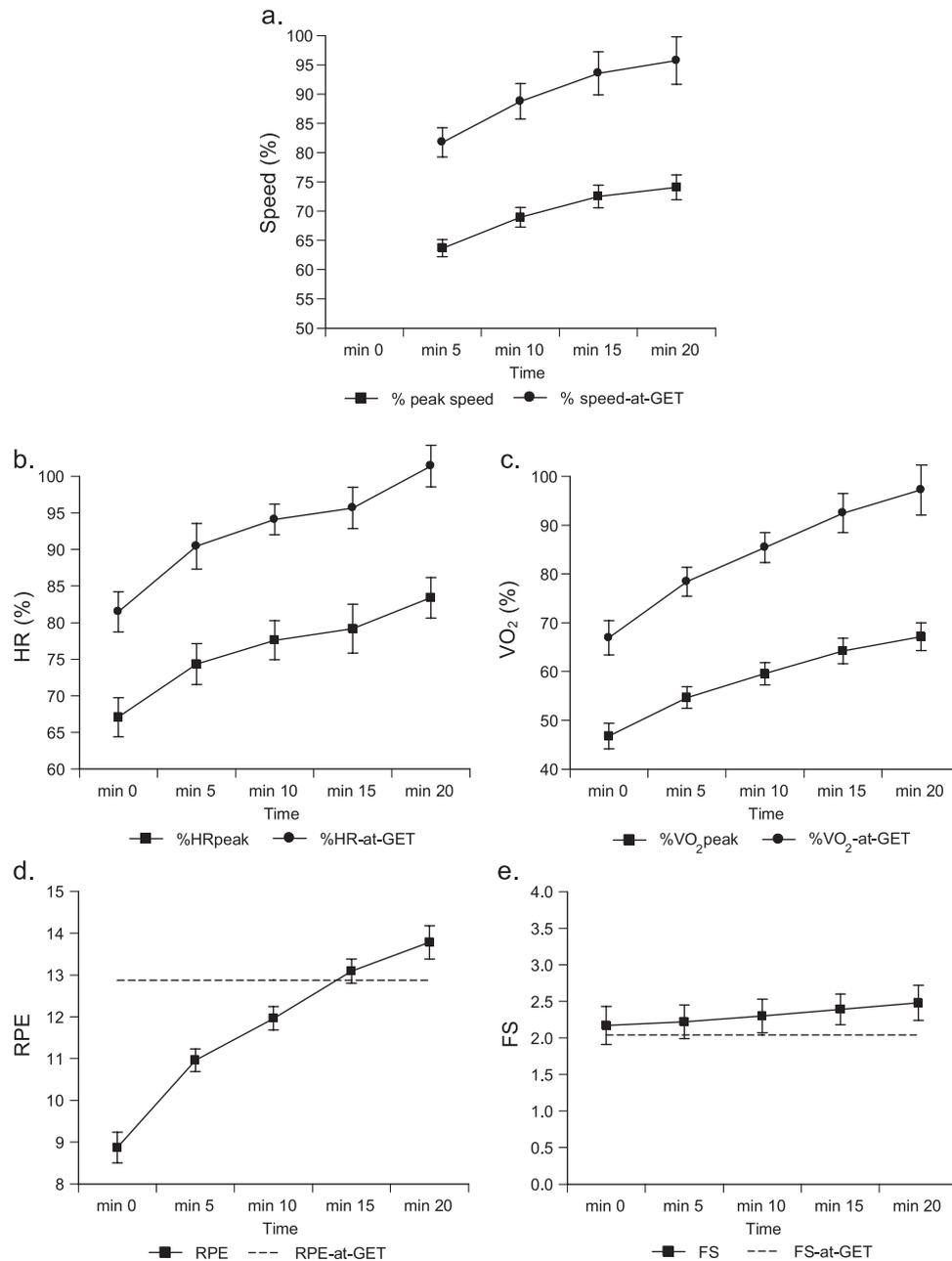
Fig. 1. Speed (panel a), %HRpeak and %HR-at-GET (panel b), %$\dot{V}O_2$peak and %$\dot{V}O_2$-at-GET (panel c), perceived exertion (panel d), and affective valence (panel e) during the exercise bout at self-selected intensity.

10, to 94% ± 18% at min 15, and, finally, to 96% ± 20% at min 20. At min 15 and min 20, there was no significant difference between the treadmill speed selected at these time points and the treadmill speed corresponding to the GET. However, it is noteworthy that, at min 20, individual percentages ranged from a low of 61% to a high of 134%.

Expressed as a percentage of the HR at GET, HR during the bout at self-selected intensity increased from 81% ± 13% at the end of the warm-up, to 90% ± 15% at min 5, to 94% ± 10% at min 10, to 96% ± 13% at min 15, and, finally, to 101% ± 3% at min 20. At min 15 and min 20, there was no significant difference between the HR recorded

at these time points and the HR corresponding to the GET. However, at min 20, individual percentages ranged from a low of 72% to a high of 140% (see Fig. 2, panels a and b).

Expressed as a percentage of $\dot{V}O_2$ at GET, $\dot{V}O_2$ during the bout at self-selected intensity increased from 67% ± 4% at the end of the warm-up, to 78% ± 3% at min 5, to 85% ± 3% at min 10, to 92% ± 4% at min 15, and, finally, to 97% ± 5% at min 20. At min 15 and min 20, there was no significant difference between the $\dot{V}O_2$ recorded at these time points and the $\dot{V}O_2$ corresponding to the GET. However, individual percentages ranged from a low of 62% to a high of 160% (see Fig. 2, panels c and d).
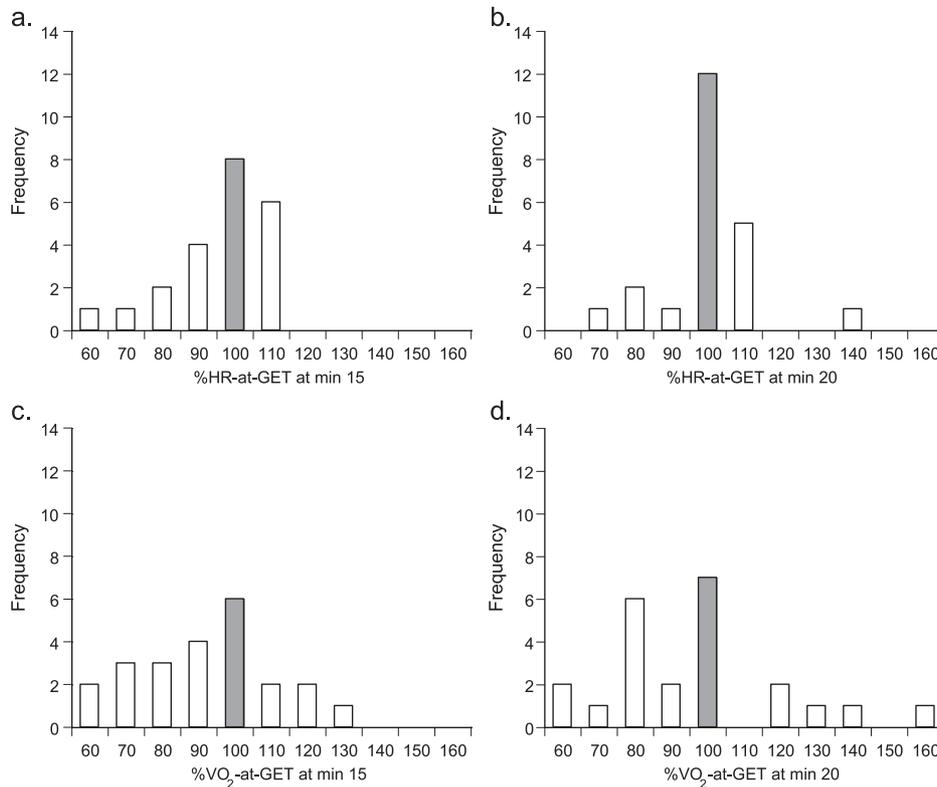
Fig. 2. Frequency distributions of %HR-at-GET observed at min 15 (panel a) and min 20 (panel b), and %V̇O₂-at-GET observed at min 15 (panel c) and min 20 (panel d) of the exercise bout at self-selected intensity. In all cases, selecting an intensity level approximating that associated with the GET was the modal response (see gray bars at the 100% categories).

Likewise, RPE at min 10, 15, and 20 was not significantly different from the RPE at GET (12.87 ± 2.53; almost "somewhat hard"). FS showed no significant difference from the FS at GET (2.04 ± 1.33; between "fairly good" and "good") at any point during the bout at self-selected intensity.

Discussion

The general purpose of this study was to initiate the systematic investigation of mechanisms directly pertaining to the physical activity stimulus itself (as opposed to social or social–psychological influences) that may contribute to dropout during the critical early stages of physical activity participation. In particular, the intensity of the activity was the focus because of evidence linking it to adherence and dropout [21,38,61,75,79] and the emphasis placed upon the postulated intensity–adherence connection in many recent physical activity recommendations. For example, according to the American College of Sports Medicine, "risk of cardiovascular and orthopedic injuries is higher and adherence is lower with higher intensity exercise programs" [3]. Similarly, according to the National Institutes of Health Development Panel on Physical Activity and Cardiovascular Health, "moderate-intensity physical activities are more likely to be continued than are high-intensity activities" [68].

An additional important and oft-expressed assumption is that the relationship between intensity and adherence is mediated by affect. Specifically, it is assumed that higher intensity of physical activity is associated with less pleasure and enjoyment or more displeasure and discomfort, and in turn, these affective responses reduce adherence and increase the risk of dropout. This assumption is reflected in the text of the Healthy People 2010 program, which states that "each person should recognize that starting out slowly with an activity that is enjoyable. . .is central to the adoption and maintenance of physical activity behavior" [87]. Thus, as suggested recently by Ekkekakis et al. [36], affect should be used as a guide in physical activity prescriptions, particularly among those just starting an activity program, and should be included as a mediator in studies examining the intensity–adherence connection.

The specific question that was examined in this study involved the level of physical activity intensity that previously sedentary, middle-aged women spontaneously select when they first start being physically active. Unlike the few previous exploratory studies that were mainly concerned with whether the self-selected intensity among regular participants tends to be within the recommended range for health and fitness benefits, the present study (a) concentrated on women that had been inactive for prolonged periods of time and (b) examined an a priori hypothesis. Specifically, based on evidence (outlined in the introduc-

tion) showing that (a) an intensity that exceeds the level of transition from aerobic to anaerobic metabolism poses an adaptational problem by tapping into an energy reservoir of very limited capacity, (b) such an intensity is accompanied by significant declines in affective valence and consistent ratings of perceived exertion, (c) given a choice, individuals will generally adjust their pace during exercise to maintain (or improve) their affect, and (d) endurance athletes typically select an intensity that is not different from their individual level of aerobic–anaerobic transition, we hypothesized that the selected intensity would, on average, (a) approximate the level of transition from aerobic to anaerobic metabolism, (b) be associated with ratings of perceived exertion in the 12–14 range, and (c) be associated with stable, positive ratings of affective valence.

The results showed the following. First, consistent with previous studies [67,82], we found that the mean intensity that the women self-selected was within the range (i.e., between 55–65% and 90% of HRmax) recommended by the American College of Sports Medicine for the improvement and maintenance of cardiorespiratory fitness [3]. In the present study, the mean intensity ranged from 67% to 83% HRmax, values similar, albeit somewhat higher, to the 69.7% reported by Spelman et al. [82] and the 67.3% (or 78.5%, when participants were instructed to walk "briskly") reported by Murtagh et al. [67]. The higher percentages in the present study can perhaps be explained by the physically inactive status, older age (43 years, compared to 35 and 40 years, respectively), higher body mass index (27 m/kg^2, compared to 24 and 24 m/kg^2, respectively), and lower aerobic fitness (23 mL kg^{-1} min^{-1}, compared to 36 and 32 mL kg^{-1} min^{-1}, respectively) of the women in the present study.

Second, our hypothesis regarding the presence of a coherent pattern of physiological, perceptual, and affective markers of intensity was confirmed. Following an initial period of gradually increasing intensity that lasted, as expected [16], approximately 10 min, treadmill speed, HR, and $\dot{V}O_2$ started to stabilize, with none of the three markers showing a significant change between min 15 and min 20. As hypothesized, there was no significant difference between the intensity selected at min 15 and min 20, and the intensity corresponding to the GET. Although with considerable interindividual variability, the lactate concentration immediately after the bout at self-selected intensity was 3.34 mmol L^{-1}, close to the 4 mmol L^{-1} value (termed the "onset of blood lactate accumulation") commonly regarded as the hallmark of the transition to anaerobic metabolism. Likewise, the RPE recorded at min 10, 15, and 20 was not significantly different from the RPE at GET (i.e., 12.87). Also as hypothesized, the values at these time points (i.e., 11.96, 13.09, and 13.78) were precisely within the range (i.e., 12–14, or from between "light" and "somewhat hard" to between "somewhat hard" and "hard") that was expected on the basis of previous studies on the RPE values that occur near the GET [27,50,76]. Finally, the ratings of affective valence (assessed with the FS) remained

unchanged throughout the bout at self-selected intensity and were all within the positive (or nonnegative) range (i.e., from "neutral" to between "good" and "very good"). Importantly, the mean rating at each time point was not significantly different from the FS associated with the GET. What the remarkable consistency of this pattern suggests is that, within a substantial margin of interindividual variability (to be discussed next), individuals spontaneously gravitate toward an intensity that approximates the level of transition from aerobic to anaerobic metabolism. We speculate that the reason is that this is the level that, individual differences notwithstanding, permits the maintenance of a stable, positive affective valence, whereas exceeding this level would initiate a substantial decline in valence [1,11,36,48]. There have been no previous studies examining FS responses in relation to the GET in self-selected intensity conditions. However, previous studies examining physiological and RPE responses under such conditions are mostly consistent with the present findings. For example, in a group of 11 trained cyclists, there was no significant difference between the intensity associated with an RPE value of 12–13 and the intensity of the GET, when these were expressed as $\dot{V}O_2$, %$\dot{V}O_2$max, HR, or power output [42]. In a group of women (mean age 35.4 years), the RPE associated with the GET was 12.9 among 20 beginners and 12.7 among 20 habitual exercisers, and these values were not different from the values they selected for their exercise sessions (i.e., 12.5 and 13.2, respectively). However, the HR associated with the GET (i.e., 128.2 and 141.6 beats min^{-1}, respectively) was significantly different from those during their exercise sessions (i.e., 151.9 and 158.2 beats min^{-1}, respectively) [83].

Third, a striking feature of the data was the considerable amount of interindividual variability, particularly in the physiological markers of intensity. Although the group averages exhibited the consistent pattern described in the previous paragraphs, many of the participants chose intensity levels that were either considerably lower or considerably higher than average (see Fig. 2). Investigating the consequences and sources of this variability is the obvious next challenge in this line of research. Previous studies have suggested that aerobic fitness and activity experience is one important source. In a study by Dishman et al. [32], low-active participants chose to cycle at intensities approximating 120% ± 10–15% of the minute ventilation associated with the GET, whereas high-active participants gradually increased their intensity from approximately 90% to 110% ± 10% of GET. Similarly, in a study by Swaine et al. [83], a group of beginners chose to exercise at 118% of the HR associated with the GET, whereas a group of habitual exercisers chose to exercise at 111%. Along similar lines, in an earlier study of men aged 19 to 66 years, after controlling for weight, height, and body composition, maximal aerobic capacity was shown to be a significant predictor of walking speed, whereas age was not [24].

The fact that, on average, participants tended to choose intensities of physical activity that approximated the level of transition from aerobic to anaerobic metabolism is positive. Ekkekakis et al. [36] have provided a synopsis of the arguments in favor of using the aerobic–anaerobic transition as a desirable point of reference for physical activity prescriptions. First, physical activity performed at or just below the level of the aerobic–anaerobic transition confers similar benefits compared to activity of higher intensity among previously sedentary individuals. Second, when the intensity corresponds to the individually determined aerobic–anaerobic transition, physical activity can be more effective in improving indices of fitness and/or health than prescriptions based on general percentages of maximal capacity. Third, physical activity intensity that exceeds the level of the aerobic–anaerobic transition may produce more adverse effects (e.g., cardiac problems) than lower intensity physical activity, particularly in certain vulnerable populations. Fourth, physical activity performed at an intensity equal to or just below the level of the aerobic–anaerobic transition can be continued for a long time, whereas an intensity that significantly exceeds this level precludes the maintenance of a physiological steady state, leads to fatigue, and creates the need to discontinue the activity.

On the other hand, what is disconcerting is that, despite providing ratings of affective valence and perceived exertion that do not indicate excessive strain or discomfort, some participants choose intensities that may, in fact, be excessive (i.e., exposing them to increased risk of injury or cardiovascular complications). Dishman et al. [32] first commented on this phenomenon. After observing that low-active and high-active participants rated their exertion similarly, despite significant differences in actual physiological indices of intensity, these authors noted that "RPE at preferred intensities of exercise can uncouple from indicators of relative metabolic intensity typically linked with RPE during grade- or load-incremented exercise or intensity production tasks" [32]. Discussing the implications of some individuals "uncoupling" their perceptions or reports of exertion from actual physiological intensity to a large degree, Dishman also posed the questions: "How can we teach [people] to more accurately estimate and produce a prescribed exercise intensity? What is the impact of RPE errors on inactivity or on risk of injury?" [29]. These questions remain unanswered but finding answers should be a priority in the exercise science and public health research agendas.

Although the magnitude of the interindividual differences is remarkable, it is not unexpected. The variation in preferred intensity may be due to (a) genetically determined traits, (b) behavioral dispositions shaped by individual experiences and developmental histories, and (c) situational factors. First, studies in both animals [45,63,84] and humans [81] are beginning to uncover the genetic bases of individual differences in physical activity patterns, but the knowledge in this area remains limited. Personality traits are also

relevant. One example is extraversion, which is, at least in part, genetically determined [40]. In an earlier study by Morgan [66], after exercising on a cycle ergometer across a wide range of workloads (from 147 to 245 W), nine male participants were asked to indicate their preferred workload. These preferences showed a strong correlation ($r = 0.70$) with extraversion scores. Extraversion was also negatively related (from $r = -0.62$ to -0.71) to RPE. Second, among the relevant dispositions that are primarily determined by individual experiences and developmental histories, self-efficacy is the one that has received the most research attention. In an illustrative example, Ewart et al. [39] reported that self-efficacy for exercise predicted the number of minutes cardiac patients spent exercising above or below their target hear rate range. Self-efficacy has also been found to relate negatively to RPE [73,78]. Third, situational factors have also been found to influence the preference for physical activity intensity. For example, the presence of observers, particularly if it is perceived to create an environment of evaluation, has been shown to increase the selected intensity of physical activity [37,43,90]. Likewise, exercising in a group setting, as opposed to the isolation of a laboratory, may also be influential due to the tendency to "keep up" with others. Recall, for example, the consistent findings of women exceeding their target heart rates when participating in group aerobics [20,26,59].

Future research should continue the investigation of individual-difference factors related to the selection and tolerance of physical activity intensity, such as those discussed above. Additionally, examining the consequences of imposing an intensity that exceeds the preferred level, even by a small margin, could yield important conclusions for the prescription of physical activity, as well as for the study of adherence and dropout.

When interpreting the results of the present study, researchers should take into account the limitations inherent in its methodology and design. First, as with most experimental research, one should not assume that the findings will generalize to other populations (e.g., men, patients with symptom-limited exercise capacity, etc.) or other ecological settings (e.g., exercising outdoors or in a social environment, such as a fitness or rehabilitation center). Second, although we chose treadmill exercise based on the fact that walking is the most familiar and popular mode of physical activity among adults, the treadmill itself may be unfamiliar and intimidating to individuals who lack experience with motorized exercise equipment. Third, as noted in the results, some individuals produced higher levels of physiological variables during the bout at self-selected intensity than they did during the incremental treadmill test (e.g., 145.16% of the lactate concentration after the treadmill test or 118.40% of HRpeak). Although it is possible that these results were due to the drift associated with an activity of longer duration than the incremental treadmill test, it is also possible that some individuals terminated the incremental treadmill test before reaching their true peak.

This is likely, given the fact that the participants had been physically inactive for extended periods of time and, consequently, might have tended to exaggerate or become apprehensive of some of the unfamiliar somatic sensations that they were experiencing. Although exercise testing serves an important diagnostic function and is desirable, if not necessary, for previously sedentary, middle-aged, and older individuals who are beginning an activity program, future investigations that involve assessments of the peak aerobic capacity in such individuals should preferably provide some opportunity for participants to familiarize themselves with exertion-related sensations before testing.

In conclusion, this study showed that formerly sedentary middle-aged women selected an intensity of physical activity that (a) was within the range recommended by the American College of Sports Medicine for the development and maintenance of cardiorespiratory fitness [3], (b) was not physiologically different from the intensity corresponding to the GET and, presumably, to the level of the aerobic–anaerobic transition, (c) was associated with ratings of perceived exertion in the 12–14 range, and (d) was accompanied by stable, positive ratings of affective valence. Beyond these average patterns, however, there was substantial interindividual variability in the selected intensity. Future studies should investigate the sources of this variability, as well as its possible consequences for adherence and dropout.

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