Physical activity for physiologists

Our understanding of the physiological changes which take place during exercise and physical activity has improved enormously over the past few decades, but physiologists are missing out on the opportunity to get even more out of their research.

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Human physiologists spend a great deal of time characterising their participants in research studies with sophisticated and often highly expensive measures to get a better understanding of their 'subjects'. However, there is very little effort to characterise physical activity and, instead, participants are usually loosely described using terms such as 'sedentary', 'recreationally active' or something similar. This is hampering future progress.

The terms 'exercise' and 'physical activity' were carefully defined almost 30 years ago but physiologists still tend to use the terms interchangeably. According to these definitions, physical activity represents any movement or force that increases energy expenditure above rest whereas exercise is a subcomponent of physical activity that is structured or planned (Caspersen *et al.* 1985). This is not just splitting hairs – whilst physiologists may be satisfied that participants will be able to tell them about their exercise participation this is missing something much more important – physical activity energy expenditure.

Some people may tell you that they are sedentary when this is clearly not the case

Figure 1 shows physical activity energy expenditure for four different middle-aged men described in more detail elsewhere (Thompson *et al.* 2012). One of these (B) has engaged in structured exercise with prolonged bouts in the morning and evening. The others have engaged in no exercise but nonetheless show enormous variability in physical activity energy expenditure. As physiologists, would we expect A to respond to either acute exercise or an exercise/physical activity intervention in the same way as C or D? Would we expect D, with an equivalent Physical Activity Level or PAL (total energy expenditure/resting metabolic rate) to B, to appear equivalent from a physiological perspective? I suspect not – and yet this is rarely considered even though we now have the technologies to do so.

An exercise 'prescription' represents a supplementary stimulus

Even a person with a very low level of activity in the sedentary range (e.g. a PAL of 1.30) expends several hundred kilocalories a day through physical activity (Brooks *et al.* 2004). This is similar to the energy expended in walking several miles. Crucially, PAL can vary enormously even without the participation in structured exercise. Thus, when exercise is prescribed to elicit a given physiological response, we should not assume that the baseline is zero. Figure 2 shows the extent with which structured exercise acts as a supplement to other physical activity. In this study, at week 18 of the intervention, participants were engaging in a significant amount of prescribed exercise (almost 4 hours of exercise per week at 65% of their maximum oxygen uptake), and yet this only represented 15% of physical activity energy expenditure (Turner *et al.* 2010). We should

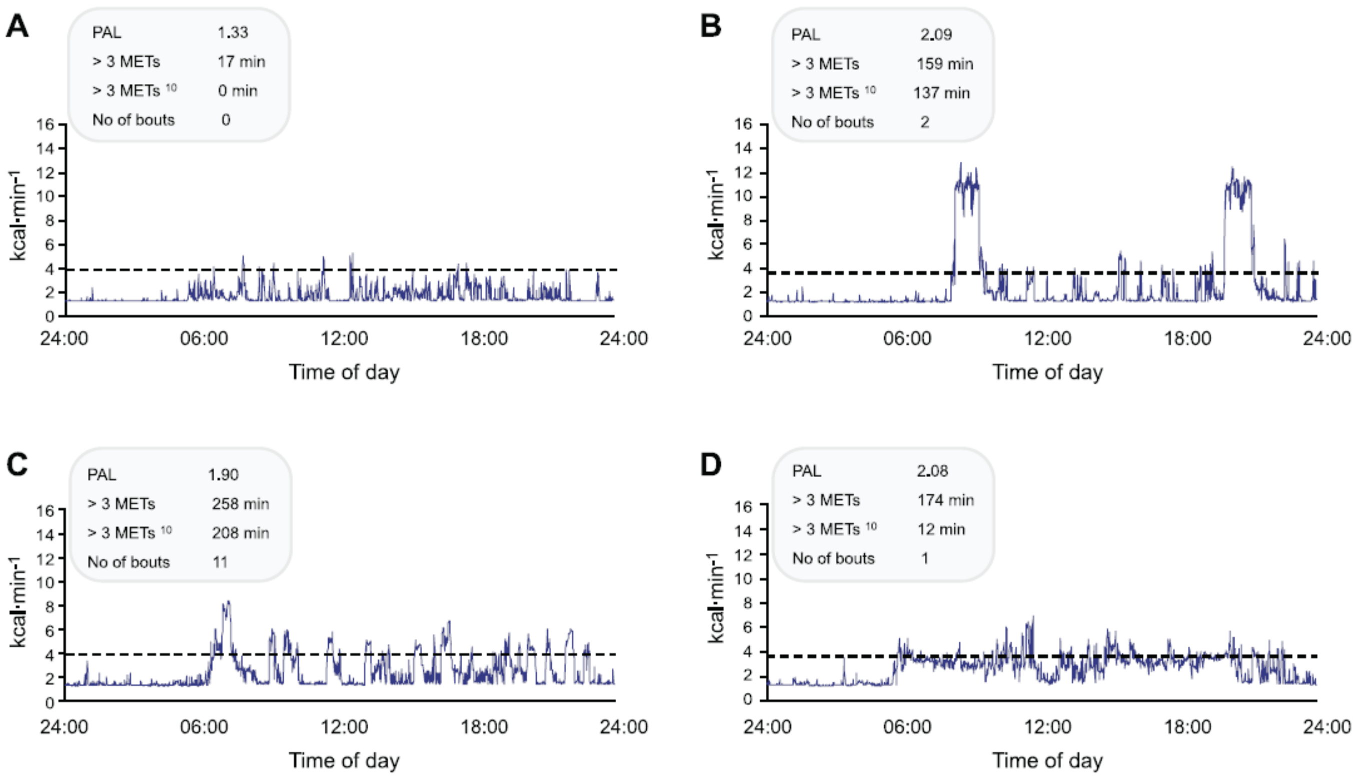

Figure 1. Physical activity energy expenditure over a 24 h period in four different middle-aged men (Thompson *et al.* 2012). Physical Activity Level (PAL) is the product of total energy expenditure/resting metabolic rate. METs represent metabolic equivalents where one MET is equivalent to resting metabolic rate.

ask ourselves, which is the greatest physiological stimulus at this time – the supplementary prescribed exercise or all the other physical activity energy expenditure which existed before the intervention? Certainly, there is strong evidence that low level physical activity is enormously important for many different outcomes (Levine *et al.* 2006; Hamilton *et al.* 2007), with perhaps some of the best evidence coming from studies showing profound physiological changes when it is taken away (Thyfault & Krogh-Madsen, 2011; Breen *et al.* 2013). Thus, it is clear that exercise cannot be treated in the same way as with the introduction of a new drug (i.e. absent before prescription) since 'new' exercise only supplements existing (variable) physical activity.

We need to explore the impact of variability in physical activity on physiological outcomes

Variation in habitual physical activity may contribute to some of the variability in response to traditional exercise interventions. The HERITAGE Family Study is a wonderful study which illustrates some of the potential variability in response to a standardised exercise prescription (Bouchard

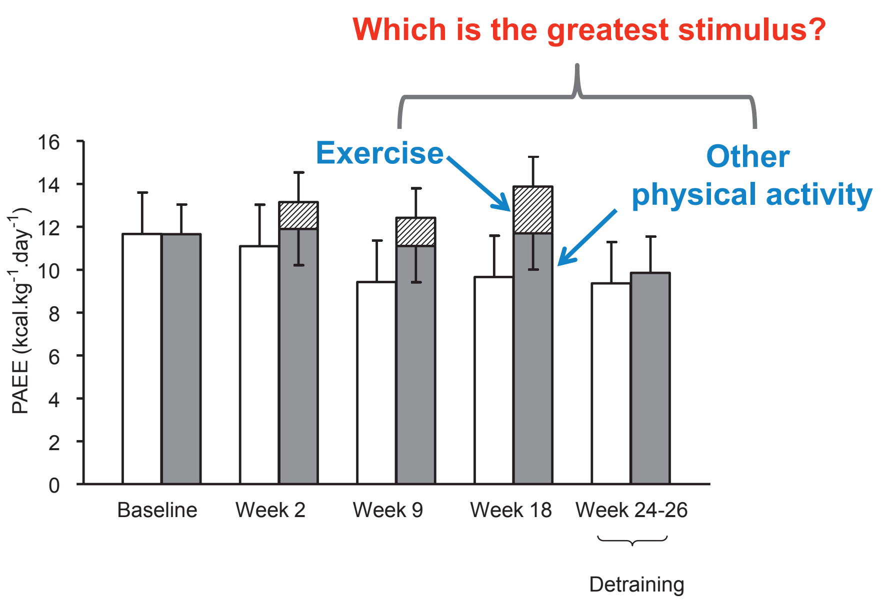

Figure 2. Which is the greatest physiological stimulus – physical activity or exercise? These data show physical activity energy expenditure (above rest) during a traditional exercise intervention (Turner *et al.* 2010). By week 18, participants were exercising four times a week for approximately 50 mins each time at an intensity of 65% maximum oxygen uptake – and yet this represents only ~15% of physical activity energy expenditure. Open bars show the control group. Shaded bars show non-prescribed physical activity energy expenditure and hatched bars show energy expenditure during prescribed exercise.

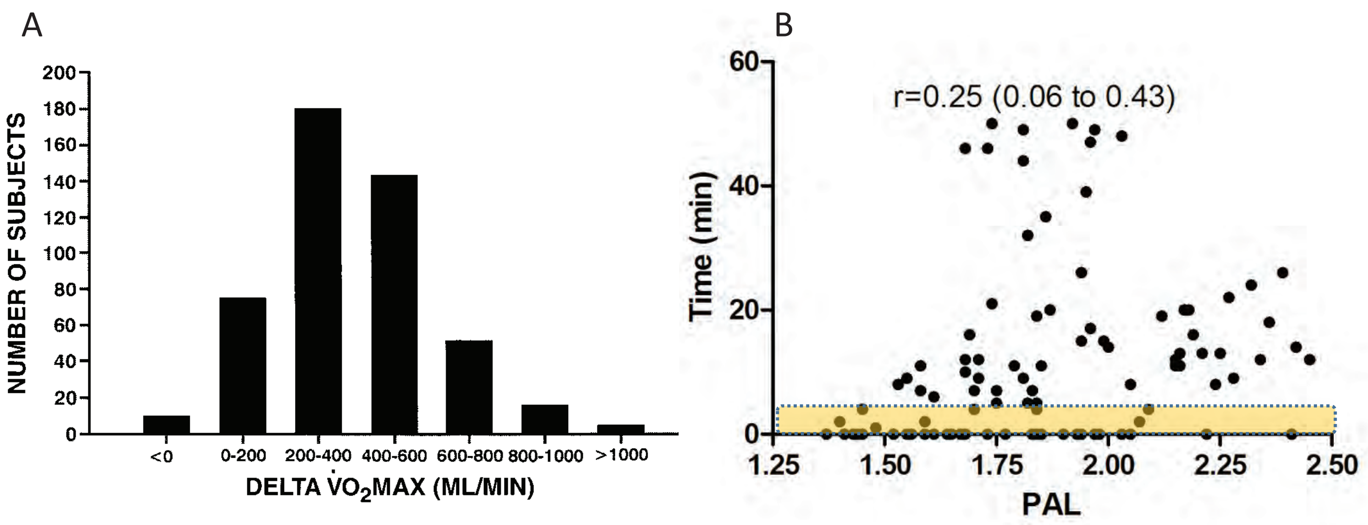

Figure 3. Variability in physiological responses to an exercise intervention alongside variation in habitual physical activity energy expenditure. A, variability in changes in maximum oxygen uptake as shown in the HERITAGE study (Bouchard *et al.* 1999); B, the relationship between time engaged in physical activity above 7.2 METs (similar to the threshold used to recruit participants to HERITAGE) expressed against PAL (Thompson & Batterham, 2013). The people in the orange shaded box in panel B would be included in studies such as HERITAGE but clearly there is enormous variation in PAL (ranging from physical activity energy expenditure of a few hundred kilocalories to more than 2000 kilocalories per day).

et al. 1999). It is worth noting that in HERITAGE participants were recruited based on self-reported participation in physical activity greater than 7 or 8 METs (depending on age). This is perfectly reasonable given the techniques that were available in the 1990s. However, as shown in Fig. 3, it is quite possible that some of the variability in training-induced outcomes such as maximum oxygen uptake reflects variation in pre-training habitual physical activity below this 7 or 8 MET threshold. For some individuals, prescribed exercise in HERITAGE will have reflected an enormous supplement and in other cases it will have been tiny in comparison to all their other physical activity energy expenditure. Since this pre-existing habitual physical activity has a major impact on maximum oxygen uptake, insulin sensitivity, postprandial skeletal muscle protein synthesis and so on (Thyfault & Krogh-Madsen, 2011; Breen *et al.* 2013), then we cannot know how much of the documented inter-individual variability in HERITAGE reflects variability in baseline pre-intervention physical activity. Of course, this is likely to be outcome specific and will not be the same for all physiological parameters. However, if we want to separate out true biological variability, we should capitalise on technological innovation and account for any variability in a given response that has been introduced because of inter-individual variability in pre-intervention habitual physical activity.

Exercise substitutes for other physical activity

Prescribed exercise in traditional intervention studies will rarely replace absolute rest and instead substitutes for other physical activity. Variability in habitual physical activity will affect the degree of substitution. Indeed, for an individual with a relatively high level of baseline physical activity, it is quite possible that a modest exercise prescription simply substitutes for similar intensity non-exercise physical activity. It is therefore unsurprising that prescribed exercise interventions do not always lead to an increase in overall energy expenditure or supplement other physical activity whatsoever (Goran & Poehlman, 1992). A more careful characterisation of the physical activity of our participants will help us to compare the results between studies in order to understand the impact of our interventions.

The picture gets uncomfortably complex …

This might already seem complicated enough but, unfortunately, the picture becomes even more complex. For example, using the same robust data for physical activity energy expenditure, approximately 90% of middle-aged men can be simultaneously described as both 'active' and 'not sufficiently active' according to current physical activity recommendations (Thompson *et al.* 2009). As shown in Fig. 4, some people with very high physical activity energy expenditure will be labelled as not sufficiently active (and vice versa). Part of the explanation for this finding comes down to semantics but, in a recent study, we demonstrate that at least some of the problem comes down to the inherent heterogeneity in a given individual's physical activity (Thompson & Batterham, 2013). In this paper we proposed that novel approaches to capture (rather than ignore) the different physiologically important dimensions of physical activity are needed.

Implications for future research

Human physiologists are missing an opportunity to make more sense of their findings and to help move the field forwards. There are numerous reasons why physiologists should be looking to integrate measures of physical activity alongside other routine measures. These include (1) to characterise their participants in order to better understand their 'subjects', (2) to quantify any inter-individual variation in habitual physical activity energy expenditure

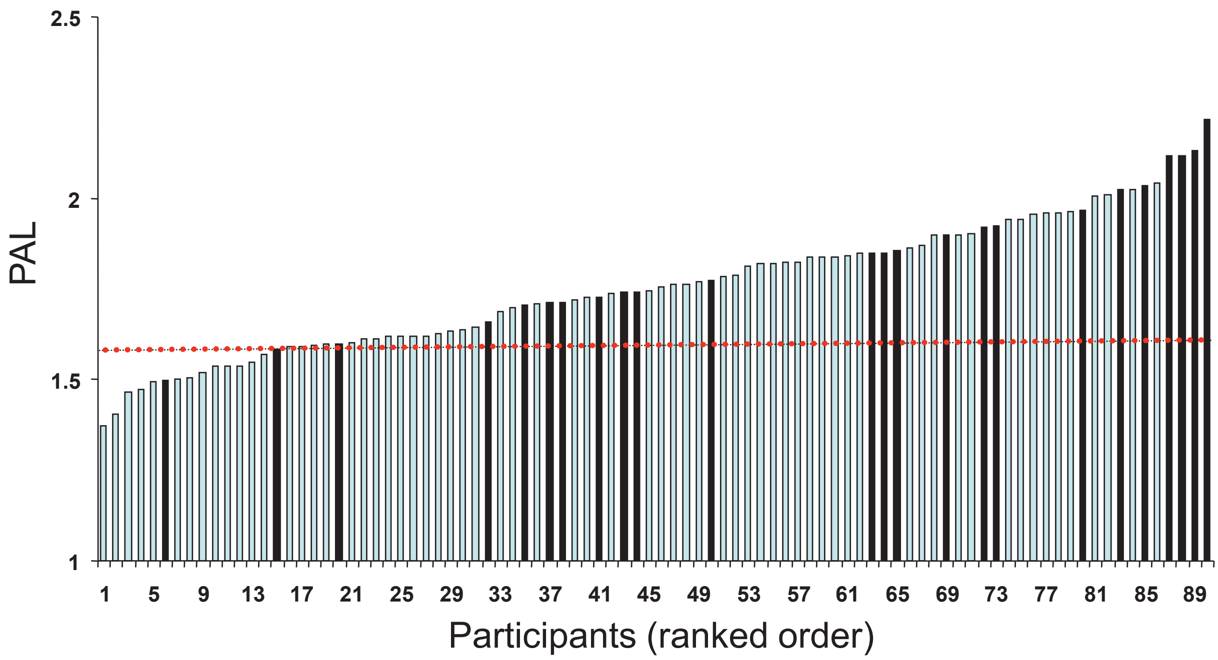

Figure 4. Ranked physical activity energy expenditure (PAL) for 90 middle-aged men (Thompson *et al.* 2009). The red line shows a PAL threshold of 1.6: this is sometimes used to determine whether physical activity is appropriate from a health perspective. The individuals with shaded columns also met the current recommendation from the American College of Sports Medicine/American Heart Association (i.e. 30 min of moderate intensity activity on at least 5 days a week in bouts of 10 min or 20 min of vigorous intensity activity on at least 3 days in bouts of 10 min).

in order to understand whether this accounts for variation in a given physiological outcome, (3) to determine the net impact of exercise interventions and the extent with which it supplements other physical activity energy expenditure, i.e. after taking into account factors such as substitution and compensation, (4) to facilitate better comparison between published studies in different laboratories and populations, and (5) to help work towards a resolution of the problems that are inherent in current public health guidelines for physical activity.

Conclusions

Physiologists have been slow to embrace the opportunities afforded by technological innovation in the capture of free-living physical activity energy expenditure. Instead, this has been left to epidemiologists and people working in public health. Physiologists have a unique role to play and it is time to recognise that being interested in measures of physical activity does not soften the science – it just makes the science better.

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