Comments on Crosstalk 26: High intensity interval training does not have a role in risk reduction or treatment of disease

Exercising in hypoxia as an innovative treatment

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Innovative clinical strategies including high-intensity interval training (Wisløff et al. 2015) are urgently needed to tackle the unprecedented increasing prevalence of cardio-metabolic disease worldwide (Dietz et al. 2015). Among many personal and environmental factors, the beneficial effects of physical activity on weight loss through increased energy expenditure and appetite modulation are firmly established (Donnelly et al. 2009). Recent evidence (Kayser and Verges, 2013) shows that combining exercise with hypoxic exposure enhances the negative energy balance and thereby further reduces weight and improves cardio-metabolic health in the obese. Firstly, the ‗altitude anorexia‘ indicates that even short exposures to hypoxia are associated with appetite reduction, resulting from decreased activity of appetite-regulating gut hormones such as plasma acetylated ghrelin (Bailey et al. 2015). Secondly, hypoxia exposure increases the resting energy expenditure. Thirdly, mechanical load is reduced with hypoxic versus normoxic exercise to achieve similar metabolic and cardiovascular training effects. This may decrease the risk of orthopaedic injuries and increase adherence to a training programme in overweight and obese individuals. Finally, the endothelial NOS pathway and the associated compensatory vasodilatation during hypoxic exercise produce beneficial haemodynamics and cardiovascular system adaptations. The superiority of exercising in hypoxia compared to normoxia for inducing larger reductions of appetite, body fat and several metabolic risk markers, as reported recently (Haufe et al. 2008; Bailey et al. 2015), substantiates our call. To conclude, among innovative interventions to be further explored, exercising in hypoxia appears to be a cost-effective strategy for reducing body weight, insulin resistance and associated co-morbidities in obese adults.

References


Additional information

Competing interests

None declared.

High intensity interval versus moderate intensity continuous training in obese individuals: a complementary view in real world setting

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It has been recently shown that in obese men eight cycling sessions (spread over 2 weeks) of a moderate intensity continuous training (MICT: 40–50 min at ~60–70% of the maximal heart rate (HRmax)) and a high intensity interval training (HIIT: 10 × 60 s intervals at ~90% HRmax interspersed with 60 s recovery) matched for mechanical work were both effective for the improvement of aerobic fitness and fat oxidation rates during exercise (Lanzi et al. 2015). Although there was no significant difference in increased peak oxygen uptake (VO2peak), HIIT had a tendency toward promoting a more marked increase in VO2peak compared with MICT (+8% for HIIT and 4% for MICT). This improvement, likely to be related to exercise intensity (Helgerud et al. 2007), highlights that (1) HIIT may be a time-efficient training in obese individuals (Gilgen et al. 2013) and (2) it is important to continuing to promote HIIT early after initiation of training programmes to rapidly reverse the low aerobic fitness in this population (Astorino et al. 2013). Although these two points seem to attest that HIIT may be preferable to MICT, only the latter induced a significant reduction in fasting insulin and insulin resistance (Lanzi et al. 2015), suggesting the importance of exercise duration for improving insulin sensitivity in obese individuals (Houmard et al. 2004). These results, associated with the
necessity of increasing training variation and adherence in a real world setting (Lunt et al. 2014), suggest that HIIT and MICT may be two complementary training tools for improving aerobic and metabolic fitness in obese individuals.

References


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HIIT must be judged against an accurate narrative of the health benefits of ‘traditional exercise training’, accounting for the confounded use of ‘intensity’ and critically appraising the ad hoc aggregation of self-reported physical activity data used to calculate relative risk (Wen et al. 2011). Thus contrary to Wisloff, Wen *et al* did not independently consider the relationship between exercise ‘intensity’ and mortality, as intensity reflected the *product* of self-reported intensity and volume (where ‘vigorous’ included jogging). Further, a beneficial ‘single bout’ had to be 30 min or more in duration (Wisloff et al. 2006), while Lee *et al.* found > 75% of mortality was *unrelated* to physical activity (Lee *et al.* 2011). Holloway’s mechanistic benchmarks for SIT (mitochondrial and capillaries) are biomarkers unproven to *predict* disease. Further, SIT should address primary prevention as efficacy of exercise for secondary prevention may be age or disease time course dependent (Karvinen *et al.* 2015). SIT and HIT yield gains in aerobic fitness, equal or superior to lower intensity training, yet only Wisloff points at the elephant in the room: namely there is no trial proving that increased $V_{\text{O2peak}}$ (by exercise) leads to a longer or healthier life. Identification of a practical time-efficient HIT ‘protocol’ that modifies *prognostic* biomarkers for health (e.g. diabetes) in a large cohort is now key. Finally, the most profound and least discussed consequence of the annestic reintroduction of ‘SIT’ to the literature is that the *specificity* between mode of exercise and physiological signal(s) for aerobic adaptation need to be entirely re-appraised (Place *et al.* 2015).

Additional information

Competing interests
None declared.

Do not write off supramaximal exercise just yet

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Interestingly, this debate appears to write off supramaximal SIT as a feasible exercise intervention. Intuitively this seems reasonable, as performing the most commonly studied supramaximal SIT protocols, consisting of four to seven repeated all-out Wingate sprints, is highly fatiguing and requires strong motivation. However, a physiological justification for the design of these protocols is lacking, and several studies have demonstrated that performing SIT protocols incorporating shorter (10–20 s; Hazell *et al.* 2010; Metcalfe *et al.* 2012; Zelt *et al.* 2014) and/or fewer sprints (two to three; Metcalfe *et al.* 2012; Gillen *et al.* 2014) does not attenuate the associated health benefits. Importantly, protocols with fewer/shorter sprints are associated with substantially lower ratings of perceived exertion (Metcalfe *et al.* 2012), and only these protocols truly achieve the much- emphasised ‘time-efficiency’ of SIT and HIIT protocols. Despite decades of research demonstrating the benefits of aerobic exercise, the uptake

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of, and adherence to, such exercise remains low. Therefore, it is time to consider providing alternative/adjunct exercise regimes, alongside current recommendations, which address the common barriers to exercise participation. There is currently no experimental evidence suggesting that supramaximal SIT is unsafe and/or poorly adhered to, and dismissing out of hand this type of exercise as unsuitable for sedentary individuals, or indeed for patient populations, may result in a missed opportunity. The best exercise intervention is one that is both effective and adhered to, and for some people this could conceivably involve time-efficient supramaximal SIT.

References


Additional information

Competing interests
None declared.

Skeletal muscle, physical exercise and health

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The CrossTalk debate between Wisloff et al. (2015) and Holloway & Spriet (2015) on whether or not ‘high intensity interval training (HIIT) does have a role in risk reduction or treatment of disease’ has discussed experimental findings which show that, in general, physical exercise has beneficial effects on our health with little if any adverse effects. The disagreement is on which form of exercise, the time-saving (weekly) HIIT or the time-consuming (daily) endurance training (ET), is better overall. On balance, I am inclined to agree with Holloway & Spriet (2015, their rebuttal) that ‘it is premature to suggest that 1 day per week of any form of exercise is sufficient for optimal health’ for everyone. However, I am not an active researcher in this field but because physical exercise represents ‘contractile activity in skeletal muscle’, two other issues have come to my mind. Firstly, as established from direct experimental research, the contractile response of mammalian skeletal muscle can change by altered chronic activity (Buller & Pope, 1977); hence, in principle, different forms of physical exercise (HIIT versus ET), if continued, may lead to ‘altered muscle-fibre type distribution and contractile performance in the body musculature’, a consequence that may be considered as an adaptation. Secondly, since skeletal muscle contraction is temperature sensitive and our peripheral muscle temperature can be variable (see Ranatunga et al. 1987, 2010), a question arises whether the ideal form of exercise routine can be the same for those living in different climates and/or altitudes in the world.

References


Choosing the ‘dose’ of exercise: towards an overcoming of the best exercise training mode?

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The CrossTalk by Dr Wisloff et al. (Wisloff et al. 2015) and Drs Holloway and Spriet (Holloway ad Spriet, 2015) is concerned with the best format of exercise training to be prescribed, that is, high intensity interval training (HIIT) vs. moderate continuous training (ET). We wish to offer to the discussion a somewhat different point of view.

To date, HIIT and ET have been matched by total energy expenditure (TEE) and investigators favouring HIIT concluded that if TEE is held constant, HIIT elicits a greater increase in aerobic capacity (AC). No one study took into consideration the individual internal training load (ITL) experienced by single individuals. TEE-based exercise training is likely to impose variable cardiovascular and metabolic demands in CHF patients (Beale et al.), as a consequence of differences in ITL. Our group (Iellamo et al. 2013a,b, 2014) has repeatedly shown that when patients are trained at the same, individually tailored, dose of exercise, by means of the individualized training impulses method (TRIMPI), HIIT and ET induce similar significant improvement in AC. Also autonomic nervous system adaptations did not differ between HIIT and ET, showing a non-linear dose–response relationship, which poses some doubt as to the risk of adverse events at higher exercise doses independent of training modality (Iellamo et al. 2013b). The TRIMPI employs an algorithm that is based on the relationship between the exponential, individual, rise of blood lactate levels with the fractional elevation HR during
incremental exercise and integrates, in a single term, both the volume and intensity of exercise, that is, the ‘dose’. This dose-based approach would overcome the issue of the best exercise mode.

Many of the HIIT protocols cited by Wisloff, Coomès and Rognmo, although of shorter duration than traditionally recommended moderate intensity exercise (30 min; Haskell et al. 2007), are still of relatively long duration compared to SIT protocols, which may take ~4 min in total and elicit impressive training responses in healthy individuals (Tabata et al. 1996). Indeed, one cited HIIT protocol had a total exercise time of 40 min (Tjønna et al. 2008). HIIT and SIT appear to have differing results in terms of physiological outcomes (Tyldum et al. 2009; Gabriel et al. 2013). Thus, further work needs to be done in order to clarify the optimal exercise regime for health and disease treatment that is also truly ‘time-efficient’. Additionally, longitudinal studies could be performed to determine if the shorter time protocol of HIIT or SIT (i.e. protocols with a time significantly shorter than 30 min) would increase exercise participation as this is yet to be determined. Although the most cited reason for not meeting the recommended exercise guidelines is a lack of time, it is not necessarily true that exercise of a shorter duration would improve exercise compliance, particularly as SIT is scored either maximally or close to maximal for rates of perceived exertion (RPE). Thus, it may be postulated that the high RPE of SIT or HIIT protocols would actually disincentivise exercise in untrained subjects. However, given the promising results of HIIT/SIT training regimes in certain conditions, HIIT and SIT appear to be worth investigating further.

References

Additional information
Is HIIT truly time-efficient?
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In rebutting Wisloff et al., Holloway and Spriet (2015) caution against forgoing activities such as resistance training for health benefit. Indeed, it is increasingly evident that maintaining muscle power and cardiopulmonary fitness (CFR) are arguably the most effective secondary prevention strategies individuals can undertake during advancing age. For instance, each 1-MET improvement in CFR equates to ~10–25% reduction in mortality risk (Kaminsky et al. 2013) and muscle power better predicts future frailty and loss of independence than strength (Reid & Fielding, 2012). Wisloff et al. (2015) reported that the majority of clinical studies examining HIIT employ intensities ranging between 80 and 100% of $HR_{max}$ rather than low-volume HIIT, performed supra-maximally (e.g. ‘all-out’), yet benefits of the latter include simultaneous improvements in CFR, power...
and functional power (e.g. get-up-and-go test) (Cantrell et al. 2014; Adamson et al. 2014; Buckley et al. 2015) for a lower exercise time commitment. For example, 3 min of low-volume HIIT, performed every 5 days increases CRF (Grace et al. 2015) and muscular power (Sculthorpe et al. 2015) in sedentary ageing men, more so than is observed amongst younger cohorts (Weston et al. 2014). Furthermore, time-efficient training is pertinent to pre-surgical patients as rapid improvements in pre-operative CRF lessens surgical risk and facilitates recovery (Valkenet et al. 2011; Singh et al. 2013; Weston et al. 2016). As such, we firmly believe it is prudent to further our understanding of the potential wide-ranging health benefits of different forms of HIIT before its role in risk reduction and disease treatment is downplayed.

References

Additional information
Competing interests
None declared.

High intensity interval training: does it have a role in risk reduction or treatment of disease? First, do no harm
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For the science of clinical exercise prescription to evolve, new approaches need to be systematically evaluated. The pioneers of high intensity interval training (HIIT) should be congratulated for challenging the conservative status quo in contributing to this process. In determining whether the promising research findings for HIIT translate to a role in risk reduction or treatment of disease, the starting point should be fulfilling the maxim embodied in the Hippocratic oath, primum non nocere – ‘first, do no harm’. While comparing non-malefice directly between moderate intensity continuous exercise and HIIT is limited to observational comparisons of adverse events, early indications suggest that complications are more frequent during HIIT in participants with cardio-metabolic disease (Rognmo et al. 2012; Levinger et al. 2015). These findings are consistent with the increase in risk of sudden cardiac death and myocardial infarction during high intensity exercise, compared with rest (Albert et al. 2000). While not precluding HIIT in clinical populations, they do highlight that caution needs to be applied when advocating for HIIT in clinical practice. Herein lies the challenge. Research participants are recruited using carefully considered criteria and may vary markedly in terms of risk from the broader clinical cohort. Before HIIT can be widely implemented, guidelines are required to support practitioners in its safe and effective implementation across diverse clinical populations. Such guidelines need to consider indications/contraindications, the appropriateness of different protocols and the role of moderate intensity ‘pre-conditioning’ exercise training to reduce the risk of subsequent HIIT interventions (Riebe et al. 2015).

References


Additional information

Competing interests

None declared.

We need to be open-minded about HIITing the brain with exercise!

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One question raised within this debate is whether high-intensity interval exercise training (HIIT) alleviates hypertension, which is both prevalent and associated with impaired brain health. The study by Molmen-Hansen et al. (2012) showed an impressive therapeutic effect in hypertension (systolic blood pressure down 12 mmHg) with the so-called ‘clinical model’ of HIIT (4 min bursts at 90% HRmax; Weston et al. 2014). However, more studies are required to confirm this effect, and to determine whether such outcomes translate to the cerebrovasculature.

As both sides of this debate have demonstrated (Holloway & Spriet, 2015; Wisløff et al. 2015), research in animals and humans have shown promising and exciting effects on important predictors of health for relatively little time commitment. However, as recently reviewed (Lucas et al. 2015), almost no research exists on the impact and potential benefits of HIIT for the brain. This is alarming and surprising given the importance of brain structure and function in health and disease, and the otherwise-expanding knowledge of exercise effects on the brain. HIIT will have many intrinsic and extrinsic effects on the brain that could have both positive and negative consequences; however, research is needed to establish whether HIIT or continuous exercise stand to exert more beneficial net influences on the brain.

Finally, while the field was originally polarised (i.e. HIIT should never be used in a hypertensive population), Molmen-Hansen et al.’s findings demonstrate that we need to be more open-minded about HIIT’s potential, particularly if exercise participation is improved.

References


Additional information

Competing interests

None declared.

Personalised exercise – time to HIIT the right balance

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This topical CrossTalk sparks important debate on the role for high intensity interval training (HIIT) in risk reduction and treatment of disease. Wisløff et al. (2015) suggest HIIT appears highly effective at reducing disease risk. Furthermore, a recent meta-analysis highlights important benefits to cardio-metabolic health following HIIT (Jelleyman et al. 2015), particularly in those at risk of or with type 2 diabetes (T2DM). Specifically, HIIT resulted in a superior reduction in insulin resistance and increase in $VO_2_{\text{max}}$ compared to continuous exercise and non-exercise control groups.

In contrast to the point of Holloway & Spriet (2015), HIIT promotes improvements to cardiac structure and function, highlighting the potential of HIIT to reduce cardiac risk factors in clinical and pre-clinical populations. The feasibility of HIIT in a ‘real world’ context is often questioned. However, high rates of adherence to unsupervised exercise, without either preconditioning exercise or any adverse cardiac events, have been reported (Cassidy et al. 2016). Similarly, high adherence rates to group cycling, which incorporates HIIT, led to marked improvements in cardio-metabolic health in overweight physically inactive individuals (Faulkner et al. 2015).

Despite this evidence, the importance of alternative exercise activities cannot be ignored. For example, resistance-based exercise may provide additional benefits that would otherwise be missed if endurance exercise were performed in isolation (Shaw et al. 2015). Therefore, we suggest that while HIIT elicits several health benefits, HIITing the intensity balance is critical in order to
optimise personalised exercise interventions and benefit both individual and public health.

References


Additional information
Competing interests
None declared.

HIIT is enjoyable and increases maximum aerobic capacity, leading to long-term adherence and potential for improved cardiovascular health in patients

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The premise of this crosstalk debate is whether high-intensity interval training (HIIT) should be considered an effective and safe form of exercise to improve cardiovascular fitness in clinical populations. Holloway and Spriet argue against HIIT, based on evidence that cardiorespiratory health was worsened in hypertensive rats that performed short intervals of HIIT. However, Wisloff and colleagues argue for HIIT, since HIIT increases peak oxygen uptake ($V_{O2peak}$), which is one of the strongest markers for long-term cardiovascular health. In contrast to evidence presented by Holloway and Spriet, recent data from animals and patients with hypertension showed that HIIT improves cardiovascular fitness (Molmen-Hansen et al. 2012; Adams et al. 2015). Part of the discrepancy between arguments put forward by the two opponents could relate to the type of HIIT performed. Several variables of HIIT can be manipulated (intensity and duration of the intervals, total exercise duration, intensity and duration of the recovery), but evidence appears most in favour of interval exercises with prolonged time at high intensity (> 90% of $V_{O2peak}$) for increasing $V_{O2peak}$ (Nes et al. 2012). Furthermore, HIIT appears to be more enjoyable than moderate-intensity continuous exercise in both obese and pre-diabetes patients (Jung et al. 2015; Martinez et al. 2015), which would promote longer-term adherence to an exercise program. Finally, an exercise training study performed in 4846 patients with coronary artery disease provided promising evidence that HIIT does not increase the risk for cardiovascular events or mortality compared with moderate intensity exercise training (Rognmo et al. 2012).

References


Additional information
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None declared.

Does the amount of metabolites released by the working muscle matter?

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This interesting CrossTalk deals with the role of exercise training in the risk reduction and treatment of cardiovascular disease. To the best of my knowledge the precise mechanism(s) through which exercise protects from cardiovascular events remains largely elusive. It is supposedly a complex and multi-factorial phenomenon. In this debate two opposite theories have been proposed. One theory supports the classical endurance training method (ET), whereas the other suggests that high-intensity interval training (HIIT) is as effective as ET. Both approaches seem to provide beneficial effects. I agree with Holloway and Spriet on the lack of reliable randomized clinical trial with hard endpoints using both ET and HIIT. However, I would like to draw the attention of opponents that they have overlooked the possibility that exercise can trigger the phenomenon known as remote ischaemic preconditioning (Marongiu & Crisafulli 2014). In short, exercise appears to act as a physiological stress inducing beneficial myocardial adaptive responses at cellular level, thereby protecting the heart.
by changing its phenotype. However, to trigger the protective phenotype a certain amount of metabolites must be produced, that is preconditioning is a threshold phenomenon. Thus, probably the amount of metabolites produced during effort is an important factor in the exercise-induced cardioprotection. This raises the question of whether a short high intensity is preferable to a long mild intensity exercise to achieve this threshold of metabolite accumulation able to induce remote preconditioning.

Additional information

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None declared.

Comment on CrossTalk

“High intensity interval training does/does not have a role in risk reduction or treatment of disease”

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Considering the accepted associations between $\hat{V}O_2$ and health, there can be no argument about the merits of high-intensity interval training (HIIT); Wisloff and colleagues have repeatedly shown, using populations across the health spectrum, the superiority of HIIT over continuous exercise for enhancing $\hat{V}O_2$ and other outcomes. Their contribution to the literature is founded on consistent use of the same training procedure. However, their training studies have not used sprint interval training (SIT).

Holloway & Spriet cloud the debate by grouping all interval training into one category, and much of their cited evidence is based on SIT, which has vastly contrasting acute and chronic consequences compared to HIIT. For example, compared to continuous training SIT ($\sim 200\% \hat{V}O_2$, work:rest ratio 1:8), to our knowledge, has never been shown to give superior $\hat{V}O_2$ improvements, while HIIT ($\sim 85\% \hat{V}O_2$, work:rest ratio 4:3) has consistently been shown to be superior. The health benefits to SIT have not been directly investigated. Clearly, different training types should not be grouped together nor should different health outcomes. The debate has an emphasis on blood pressure which, even using the HIIT model proposed by Wisloff et al., has not always resulted in favourable responses. No single drug promotes all-round health and nor should we expect one type of exercise to be universally beneficial. Progress in the area can only be made if consistent training models are used and if SIT is differentiated from mere ‘high intensity’ exercise. Intensity is crucial, but maybe not always and maybe not too much!

The CrossTalk on the role of high-intensity interval training (HIIT) in disease prevention presented interesting views on the potential benefits and challenges of this exercise approach for improving health. Regardless of the ‘optimal’ exercise strategy, the fact remains that most people are inactive, as noted by both opponents. In our view, this necessitates exploring and promoting (if effective) alternative strategies to provide options for children, adults and those with chronic disease to attain health-enhancing physical activity. There is accumulating evidence that HIIT can be adapted and implemented with health benefits in all of these populations, sometimes with superiority to traditional ‘endurance training’ (ET). Many questions remain, but the key issue of adoption and adherence in the ‘real-world’ are perhaps most important for HIIT to impact health. We have shown that inactive adults rate HIIT as highly enjoyable and a majority prefer HIIT over ET (Jung et al. 2014). Furthermore, as first described by Nose and colleagues (Nose et al. 2009), HIIT can be adapted to interval walking in older adults, type 2 diabetes (Karstoft et al. 2013), and prediabetes (Jung et al. 2015). In fact, preliminary evidence suggests that short-term adherence to HIIT walking might be superior to continuous walking when prescribed with behavioural counselling (Jung et al. 2015). Therefore, it appears we can move beyond preclinical models (suggested by Wisloff et al. 2015) and reports of negative molecular remodelling in rodent hearts (Holloway & Spriet, 2015) to start considering the real-world health impact of HIIT from a flexible and interdisciplinary perspective.

Additional information

Competing interests
None declared.

References

Acute high intensity interval training confers a short-term reduction in systemic vascular resistance and increase in ejection fraction in clinically stable systolic heart failure patients

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We have read with interest the CrossTalk on whether high intensity interval training (HIIT) has a role in risk reduction or treatment of disease. We highlight two important observations. First, Wisloff et al. provide evidence suggesting that the risk for cardiovascular events in a 24 h period following HIIT may be relatively low. This is important to note, as cycling intervals near or above peak power output in endurance-trained individuals reduced left ventricular ejection fraction (LVEF) post-exercise (Scott et al. 2010). Based on this, we suspected that patients with heart failure (HF) would also demonstrate acute LV systolic dysfunction post HIIT. On the contrary, and consistent with the findings of Wisloff et al. (2007), LVEF increased 30 min post-HIIT (Tomczak et al. 2011). Second, Holloway & Spriet noted the important post-exercise hypotension benefits associated with exercise training, and suggest this effect may be less so or absent with HIIT. We found the increase in LVEF 30 min post-HIIT in HF patients was associated with a significant reduction in systemic vascular resistance (Tomczak et al. 2011). Acutely, HIIT appears to confer LV improvement and reduced LV afterload. However, it will have to be shown whether acute and prolonged benefits on LV function will translate clinically. Larger randomized trials with longer follow-up are underway to address this very question (Stoylen et al. 2012). HIIT therefore remains an option for clinically stable cardiac patients together with recommended moderately intense exercise, with appropriate caution taken, depending on clinical diagnosis, symptoms and medication.

References

Additional information
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None declared.

HIITing diabetes where it hurts

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Holloway and Spriet (2015) hang their argument on a single study in a hypertensive rat model where ‘HIIT’ consisted of a greater total workload than the endurance training control and produced a glycolytic phenotype in skeletal muscle, which as the authors admit, does not reflect the adaptation to HIIT in humans. Wisloff et al. (2015) present several lines of evidence for the health benefits of HIIT in hypertensive humans. Type 2 diabetes (T2D) is a major risk factor for hypertension and cardiovascular disease and so consideration of the role of HIIT in the management of T2D is also warranted. HIIT is more effective than moderate endurance exercise at increasing insulin signalling in adipose tissue and skeletal muscle (Tjønna et al. 2008). Moreover, in T2D patients, HIIT has demonstrated considerable efficacy in improving cardiac (Cassidy et al. 2016), β cell (Madsen et al. 2015b) and endothelial (Madsen et al. 2015a) function, as well as reducing liver fat (Cassidy et al. 2016). Importantly, these physiological changes translated to improved disease management and clinical indices of glycaemic control such as HbA1c levels, fasting blood glucose, 2 hour OGTT, and increased whole-body insulin sensitivity (Jelleyman et al. 2015; Madsen et al. 2015b). Unfortunately, adherence to prescribed exercise programmes is often poor and pharmacological intervention is typically favoured for the management of T2D, but given that time constraints are commonly cited as a primary reason for poor exercise compliance, HIIT is clearly an option for T2D and long-term (> 18 months) HIIT clinical trials are justified.

References


Additional information

Competing interests

None declared.

High intensity interval training does have a role in risk reduction or treatment of disease

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A ‘one size fits all’ exercise training programme may not exist; however, high intensity interval training (HIIT) and sprint interval training (SIT) can benefit a variety of patient populations. This is supported by long-standing investigations dating back to the mid–late 1980s that provide crucial mechanistic insight into this debate. Some examples demonstrate myriad beneficial effects of SIT and HIIT on central cardiac and peripheral vascular function in health and disease (Laughlin et al. 1988; Musch et al. 1988; Musch, 1992). With regards to the central benefits, Musch (1992) demonstrated in rats with chronic heart failure (infarct size ~35%) that 6 weeks of SIT (5 x 1 min, supra-\(\dot{V}_O_{2\text{max}}\)) resulted in an 11% increase in \(\dot{V}_O_{2\text{max}}\) when compared to pre-training values. These changes were due exclusively to elevations in maximal stroke volume as there were no differences in maximal oxygen extraction when compared to controls. These central benefits did not occur following traditional endurance training (Musch et al. 1986). Thus, central cardiac benefits are less equivocal than proposed by Drs Holloway and Spriet in their original argument. Additionally, chronic diseases may increase the reliance on Type II muscle fibres such that HIIT may be required to elicit optimal (i.e. more complete) adaptations of the peripheral vasculature (Laughlin, 2016). However, it must be acknowledged that our ‘furry friends’ in the studies highlighted above trained 5–6 days/week and this type of exercise may be contraindicated for those populations at high risk for acute chest syndrome (i.e. sickle cell disease).

References


Additional information

Competing interests

None declared.

Training, genetics and the history of Homo sapiens

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Physical activity will have been much more intense in hunter–gatherer societies prior to the current ‘Anthropocene’ period, the age of humans, but it likely varied depending on local geography. Variation in exercise types, intensities and durations at that time is relevant to consideration of the optimal exercise pattern for health in modern humans. Our physiology as determined genetically is likely to be broadly tuned so that no single exercise pattern is dramatically better than another, provided it provides sufficient stimulus for key physiological functions (such as the cardio-respiratory and musculoskeletal systems) to adapt.

Physical activity should be increased in the sedentary and it seems undeniable that some high-intensity activity should be included. Such activity will produce larger benefits in the less well trained (Place et al. 2015) although it must be done in a clinically safe way.

Consider also prescription of exercise for the sedentary elderly who usually have neurological, cardiovascular and musculoskeletal ‘conditions’ directly predisposing to falls and consequent morbidity and mortality. Physiological performance declines with age and many diseases (e.g. Lord et al. 2016). Programmes with greatest success in reducing fall incidence incorporate repeated high-force challenges to balance and are not helped by low-intensity walking (Sherrington et al. 2011).

Finally, results from the ‘HERITAGE’ study remind us that even with standardised training, improvements range from zero to doubling in parameters like \(\dot{V}_O_{2\text{max}}\) (Bouchard & Rankinen, 2001). Hence, a ‘one-size-fits-all’ approach may need refinement for practical trials and ultimately for incorporation into formal guidelines.

References


**Additional information**

**Competing interests**

None declared.

**Not one HIIT fits all**

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Investigating the impact of exercise on whole body or cellular responses is both challenging and stimulating given the complexity and variety of factors involved (Egan et al. 2010, 2013). This is compounded further when homeostasis and cellular function are disrupted in chronic disease states. It is widely accepted that exercise of varying duration, intensity and frequency mitigates this maladaptation (Booth & Laye 2010) but in most instances a generalised (Colberg et al. 2010) rather than personalised approach to exercise is adopted. This CrossTalk, debating whether HIIT has a role in the management of heterogeneous (pre-) clinical populations, serves as an exemplar to argue for a ‘Personalised Exercise Treatment’ (PET) approach to disease management. Instead of a somewhat futile justification for/against HIIT, a strategy to stratify patients and optimise treatment outcomes in sub-groups needs to be developed. As evidenced in this CrossTalk, heterogeneous clinical phenotypes and physiological adaptations have high and low sensitivity to HIIT, as with other forms of exercise. A PET approach would be informed by the type, severity and duration of disease in addition to the clinical phenotype, pharmacological treatment and the high degree of inter-individual sensitivity to exercise. Good examples of disease-specific exercise training strategies exist (Praet & van Loon 2007), but there is scope for further personalisation and diversification.

The primary clinical outcome targets for disease management can be optimised if the heterogeneous response to exercise, including HIIT, can be harnessed to identify the right exercise dependent on the patient’s individual circumstances, access and preferences.

**References**


**Additional information**

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None declared.

**High intensity interval training plays a key role in the treatment of skeletal muscle and endothelial dysfunction in cardiovascular disease**

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We followed with interest and somewhat surprise the recent CrossTalk debate. Indeed, we believe it would be rather premature to support the viewpoint that high intensity interval training (HIIT) does not have a role in risk reduction or treatment of disease, as evidenced by numerous patient studies (Wisloff et al. 2007; Conraads et al. 2015) and our recent work in an animal model of hypertension-induced heart failure with preserved ejection fraction (HFpEF) (Adams et al. 2015; Bowen et al. 2015). This disease, characterized by exercise intolerance consequent to skeletal muscle and vascular dysfunction, is particularly intriguing in that evidence from large clinical trials shows limited benefits following pharmacological interventions (Sharma et al. 2014), thus exacerbating the need to find alternative therapies. We therefore recently investigated the effects of HIIT on skeletal muscle and endothelial function in HFpEF (induced by a high salt diet over 28 weeks in Dahl salt-sensitive rats). In summary, our data demonstrated that HFpEF impaired aortic endothelial function (Adams et al. 2015) and induced contractile dysfunction in both respiratory and limb muscle (Bowen et al. 2015). In contrast, HFpEF rats performing HIIT had no skeletal muscle or endothelial dysfunction, with impairments to muscle mitochondria and endothelial nitric oxide synthase (eNOS) attenuated. While we agree, therefore, that it remains uncertain as to whether HIIT is more beneficial than continuous training (Conraads et al. 2015), we believe initial findings support a role of HIIT in the treatment of disease.

**References**


Not a question of if, but how best to employ HIIT in metabolic disease

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While we can endeavour to identify the most efficacious exercise modality to prevent or treat metabolic disease, due to a dearth of long term (>12 weeks) studies comparing high intensity intermittent interval training (HIIT), aerobic endurance training (ET), resistance training (RT) or combined ET/RT in metabolic disease (Jelleyman et al. 2015), it is myopic to classify any intervention redundant or superior. As most conditioning coaches know, training prescription should always be periodized, i.e. planned and structured specific to a training outcome, specific to the individual, and employing multiple complimentary training methods. Importantly, exercise adaptation is never binary and is influenced by genetic and non-genetic factors (Mann et al. 2014). Although well-defined, clinically-relevant endpoints are fundamental to assess efficacy of exercise interventions, comparison of group means often neglects myriad additional metabolic, cognitive and cardiovascular improvements that may not be primary outcomes, and, as indicators of efficacy, masks obvious inter-individual differences in training response (Bouchard & Rankinen, 2001). Thus, a broad range of physiological outcomes is warranted to accurately elucidate the efficacy of training regimens (Buford et al. 2013). Given emerging data concerning the individualized nature of disease pathophysiology, and complex cellular response to both exercise (Timmons, 2011) and nutrition (Zevei et al. 2015) interventions, a more periodized and personalized approach to exercise prescription is appropriate rather than a ‘one size fits all’ approach. Implementation of ‘omic’-based technologies, in parallel with longer term training studies will refine and further inform exercise prescription to meet specific, patient-focused needs.

References


Additional information

Competing interests

None declared.

High-intensity interval training may be an effective method to improve cardiometabolic health in youth

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The CrossTalk debate presents contrasting views about the effectiveness of high-intensity interval exercise (HIIE) training to modify risk and treat disease in a variety of adult populations. However, it should be recognised that HIIE has the potential to contribute to the primary prevention of disease through risk modification in youth. Cardiometabolic risk factors cluster in youth and independently predict adult health status (Laitinen et al. 2012). Although increased physical activity (PA) is related to lower risk in youth, few meet the daily PA guidelines for health. Contemporary evidence demonstrates that vigorous PA is the strongest predictor of cardiometabolic risk in youth (Carson et al. 2014) suggesting that HIIE may be a useful strategy to improve health outcomes in this population. Recent experimental work supports this notion as in contrast to work-matched moderate intensity exercise (MIE), just 8 min of HIIE provides similar or superior improvement to post-prandial triglycerides, blood pressure, lipid oxidation and insulin sensitivity in healthy adolescents (Bond et al. 2014). Interestingly, when exercise is accumulated throughout the day to reflect habitual PA patterns, only HIIE improved cardiometabolic risk in adolescents (Bond et al. 2015b; Cockcroft et al. 2015). The benefit of adolescents performing HIIE extends beyond traditional risk factors, as HIIE augments endothelial function in contrast to MIE both in the fasted and the post-prandial state (Bond et al. 2015a). As youth enjoy performing HIIE compared to MIE (Bond et al. 2014), we believe that HIIE may also have an important role to play in modifying risk in youth.

References

HIIT’s capacity to elicit similar benefits to ET, despite (typically) involving less time, should favour its implementation. Second, HIIT is more representative of the daily activity challenges of many clinical populations. Considering the low fitness levels of clinical populations and the MET values for various activities (Jette et al. 1990), HIIT’s short-bouts of ‘high-intensity’ exercise are comparable to completing many activities of daily living (e.g. climbing stairs or carrying groceries). Thus, in addition to providing a sufficient stimulus for adaptation, HIIT may also decrease barriers to activity by increasing confidence in the ability to complete brief, high-intensity activity outside of the ‘gym’. If our goal is to get people moving, HIIT is a time-efficient strategy that provides a potent physiological stimulus. We agree more research is required to fully understand HIIT’s health benefits, risks and optimal prescription. However, consider the decades of research it took to shift our ideology from bed rest to ET for the treatment of cardiovascular diseases. While we build our knowledge base, the benefits of an ‘active’ approach that supports the inclusion of HIIT into our exercise prescriptions should outweigh any elevation in risk compared to ET.

Reference


High-intensity interval training: a little of something is better than a lot of nothing

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We would like to commend the authors of this CrossTalk debate for their thorough overview of the evidence to date, and would like to add two considerations to the discussion. First, the emphasis on whether HIIT elicits superior benefits to ET is superficial. Given most individuals are not satisfying physical activity guidelines, which are dominated by ET recommendations, training (HIIT) is ideal for reducing risk and treating disease.

Ideal exercise prescription may be dependent on the goal, chiefly primary prevention versus secondary prevention and disease treatment. The example Holloway utilizes (Holloway & Spriet, 2015) of blood pressure management is particularly complex, given the multiple aetiologies of hypertension. Our mechanistic knowledge of vascular signals during acute bouts of exercise is still developing (Crecelius et al. 2014). Given this, we may still have a way to go in understanding (1) the different means by which CME and HIIT affect these signals, and (2) the ability of different training paradigms to prevent and/or treat pathologies, particularly of the vasculature.

An important point from Wisloff and colleagues is the ability of HIIT to improve peak $V_{\text{O}_2}$ to a greater extent than CME (Wisloff et al. 2015). This is significant, given the greatest determinant of independent living with age may be $V_{\text{O}_2\text{max}}$ and small improvements can increase survival 10–25% (Paterson et al. 2004; Kaminsky et al. 2013). Thus, the broad benefit of HIIT in patient populations is worth continued exploration.

Even if we reached consensus on a prescription, patients’ adherence remains a challenging goal. Thus, we conclude with wisdom offered by Hippocrates, ‘It is more important to know what sort of person has a disease than to know what sort of disease a person has.’

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Additional information
Competing interests
None declared.

HIIT and aerobic training are like apples and oranges ... both are better for you than being sedentary

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Although both sides presented valid points with support from the broader literature, a glaring omission in the discussion pertaining to the role of HIIT versus MICT is the effect of both exercise modalities on cerebrovascular and cognitive health. While a lifetime of aerobic training decreases the physiological age of the cerebrovasculature by ~10 years (Ainslie et al. 2008), the relative effects of HIIT on the cerebrovasculature are entirely unknown, and need to be explored (Lucas et al. 2015). Exercise may reduce cognitive decline and protect against dementia, supported by the estimation that 12.7% of Alzheimer’s disease cases could be prevented by addressing physical inactivity (Barnes & Yaffe, 2011). However, no randomized controlled trials exist evaluating the benefit versus harm of either exercise type for prevention of dementia (WHO, 2012). In contrast to the prompt of this debate, it is pertinent to consider the value of shifting the current discussion from ‘which form of exercise is optimal’, to focus on how to facilitate activity. It doesn’t matter which form of exercise elicits the greatest physiological adaptations or risk reduction if the population is not motivated to undertake that modality. In Canada, ~43.6% of the population is inactive based on current physical activity guidelines, which equates to ~$3 billion in direct healthcare costs, with an additional ~$7.5 billion in indirect costs (Krueger et al. 2015). Thus, although HIIT may induce greater cardiovascular health benefits, just getting people active via either approach should be viewed as a success in today’s sedentary society.

References

Additional information
Competing interests
None declared.

Should the debate really be about effectiveness?

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I read with interest the CrossTalk opposing views on whether high intensity interval training has a role in risk reduction or treatment of disease. My Canadian compatriots seemingly faced the more daunting task in staking out the ‘con’ position, given the wealth of evidence available to their opponents in advocating for the ‘pro’ side. Indeed, can the efficacy of interval training really be questioned at this point? With respect to risk reduction, cardiorespiratory fitness (CRF) is a strong and independent predictor of all-cause and cardiovascular disease mortality, and seemingly at least as important as traditional risk factors such as hypertension and diabetes (Lee et al. 2010). Not only does interval training improve CRF, this type of exercise can elicit changes superior to traditional moderate-intensity continuous training despite reduced time commitment (Bacon et al. 2013). Compelling evidence has also established that interval training can play a role in the treatment of disease (Weston et al. 2014). The pioneering work of Meyer and colleagues showed in patients with heart failure that interval training facilitated an intensive training stimulus to peripheral muscles without a significant increase in cardiovascular stress (Meyer et al. 2001). More recent research has demonstrated that interval training improves indices of metabolic health particularly in those at risk of, or with, type 2 diabetes (Jelleyman et al. 2015). The real debate seems to be from a behavioural perspective, namely, the potential effectiveness of interval training and its likely impact on public health (Biddle & Batterham, 2015).

References

Additional information
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Role of high intensity interval training in risk reduction, disease treatment, injury risk and exercise adherence

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Significant muscle adaptations/exercise performance effects and improved body composition/other health biomarkers with high intensity interval (HIIT) or sprint interval (SIT) training are certainly intriguing (Gibala et al. 2014; Hazell et al. 2014; Jelleyman et al. 2015; Ramos et al. 2015). More studies are needed before definitive conclusions are possible but, importantly, many benefits seem equivalent to or even greater than traditional endurance exercise training and with a substantially reduced time commitment. These data suggest that, while moderate intensity, prolonged exercise is beneficial for both exercise performance and health, HIIT (or SIT) could be superior. Further, HIIT (or SIT) could be the answer for those who ‘don’t have time’ to exercise regularly. Critically it appears that, despite the intense nature of HIIT and, especially SIT, injury risk is similar and adherence appears to be greater vs. traditional endurance training (MacPherson et al. 2011; Hazell et al. 2014; Beaulieu et al. 2015). The mechanisms responsible for the latter effect remain unclear but may include the aforementioned much reduced time commitment, the time course of adaptations, reduced boredom, the perception that one is doing much more work, or perhaps even rewarding brain chemistry changes. Regardless, greater adherence is significant because getting people to exercise sufficiently for health has proven to be a major challenge. Further systematic study is needed to determine the underlying reason(s) for the apparent greater adherence as well as to find answers to several other important questions including the optimal exercise stimulus (intensity/bout duration, repetitions, and recovery intervals), whether/how effects differ across age groups/gender or in various diseased populations, how nutrition interacts, as well as the long term effects (months and years). Stay tuned!

References


