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Why Intensity is not a Bad Word: Optimizing Health Status at any Age

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Abstract

Age-related declines in health and function make locomotion increasingly difficult leading to reductions in non-exercise activity thermogenesis (NEAT), skeletal muscle size and strength, and increased adiposity. Exercise is an important strategy to attenuate loss of function through the life cycle. Despite claims to the contrary, high-intensity exercise is important for the prevention of obesity and sarcopenia with advancing age. Therefore, the purpose of this mini-review is to present literature supporting the contention that low volume, high-intensity aerobic and/or resistance training can slow sarcopenia, sustain ease of movement, stimulate NEAT, and attenuate the accretion of fat mass.

Keywords

High-intensity exercise; resistance training; physical activity; energy expenditure; exercise economy; sarcopenia

Introduction

Obesity continues to plague modern society with increasing incidence during the transition from middle- to early old-age. Sarcopenia (an age-related loss of skeletal muscle) is also a major problem, especially after the age of 50. Complications arising from sarcopenia, notably reduced ease of movement and participation in free-living physical activity, increases the susceptibility for increased weight gain in older adults. It is possible the development sarcopenic obesity (a combination of sarcopenia and obesity) may be a phenotypic expression of declining skeletal muscle function and physical inactivity. Several investigations have shown that sarcopenic obesity is more strongly related to disability than either obesity or sarcopenia [1;2]. In fact, a sarcopenic obesity index of < 7.26 (calculated as the ratio of appendicular skeletal muscle divided by height²) is a validated predictor of the onset of disability [3]. Strategies are needed to combat increased adiposity, and loss of skeletal muscle function. The purpose of this paper is to demonstrate that low volume, high-intensity aerobic and/or resistance training can slow sarcopenia, sustain ease of movement,

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stimulate non-exercise training activity thermogenesis (NEAT) and attenuate the accretion of fat mass (Figure 1).

Sarcopenia and Decreased Total Energy Expenditure

Sarcopenia accelerates after the age of 50 [4], with adults losing on average 5–10% of skeletal muscle mass prior to age 50 and an additional 40% by age 80. Functional measures, such as muscle strength/endurance and ease of locomotion, seems to follow a similar time course [5] (Figure 2). Furthermore, loss of type II or fast-twitch muscle fibers also occurs during aging, making the ability to perform tasks that require speed or power particularly challenging in older adults [6]. Total energy expenditure (TEE), resting energy expenditure (REE), and activity-related energy expenditure (AEE) all decrease with advancing age [5]. The decrease in muscle size, strength, aerobic fitness, and function can all be attenuated with intense exercise training, but as the decrease in performance in aging athletes clearly demonstrates, not stopped [5].

Energy Expenditure is Important in Weight Maintenance

From ages 30 to 80, REE decreases between 160 kcal ($\approx 11\%$) [7] and 330 kcal/day ($\approx 23\%$) [8], while the decrease in AEE has been estimated to be $\approx 23\%$ or 2.2 kcal/kg/day [9;10]. Low levels of physical activity, especially AEE associates with weight gain [10;11]. For example, after a dietary weight loss of 10 kg, we separated pre-menopausal women into two groups based on changes in body weight over one year (i.e., “gainers” +9 kg mean weight gain, and “maintainers” –0.5 kg mean weight loss). Using doubly-labeled water to measure TEE, we found that women who maintained weight had an average NEAT that was over 200 kcal/day higher (both after weight loss and one year later) than those who gained weight after one year (Figure 3) [10]. Interestingly, REE adjusted for fat mass and fat-free mass was not different between the “gainers” and “maintainers” – thus highlighting the importance of NEAT in long-term weight maintenance.

Although, doubly-labeled water studies clearly show the importance of AEE in preventing weight gain [11–13], no consensus can be found concerning the role of REE in weight maintenance among young adults. However, it seems likely that the large decrements in REE that occur with aging [8] make it more difficult for the middle-aged to young-old (fifth through seventh decades) to maintain weight.

Energy Expenditure during Exercise

Although energy expenditure during relatively high-intensity aerobic exercise in fit individuals can be substantial (≈ 500 – 900 kcal/hour) [14], it is difficult to lose large amounts of weight with aerobic exercise without the addition of dietary caloric restriction. Typical aerobic training performed in the absence of dieting normally results in 1–2 kg losses of body weight (most if not all fat mass). However, it is difficult for most individuals to find the time or motivation to sustain intensities/volumes of aerobic training needed to elicit significantly larger reductions in body weight. In contrast, the energy expended during typical resistance training is much less, ≈ 120 – 250 kcal/hour for women and ≈ 200 – 500 kcal/

hour for men [9]. Minimal weight loss occurs as the result of resistance training; however, reductions in adiposity are often similar to that found with aerobic training due to the gain in muscle at the expense of fat tissue [5]. Since weight loss does not normally occur with resistance training, it is generally thought that dietary compensation is more complete as a result of resistance training compared to aerobic training. However, these beliefs are incorrect as dietary compensation with aerobic training is at least as large, if not larger than with resistance training. For instance, our group has demonstrated that net energy expenditure in a group of older men and women was 119 kcal for 45 minutes of high-intensity resistance training [15]. The men and women trained 3 times/week for a total of 357 kcal/week of exercise energy expenditure or an average of 50 kcal/day. However, TEE increased +230 kcal/day by the end of the 26 weeks due to additional increases in REE and NEAT. Although the TEE increased +230 kcal/day at the end of 26 weeks, the increase would be expected to be gradual across the 26 weeks of training. If the assumption is made that little change occurred during the first days of training and increased gradually over the 26 weeks of training, it might be assumed that the average increase in TEE is approximately 50% of the value measured after 26 weeks, averaging ≈ 115 kcal/day over the baseline value for an increase in cumulative energy expenditure of 20,930 kcal ($115 \text{ kcal/day} \times 182 \text{ days}$). Although body weight did not change, the participants gained +2 kg of fat-free mass and lost -2.7 kg of fat mass. Strategies that impact NEAT may be particularly important in the fight against obesity since participation in NEAT is very low in obese individuals [16].

Using procedures previously described [17], the loss or gain of kcals contained in the body across any time period can be determined by measuring changes in fat mass and fat-free mass [17]. The gain of 2 kg of fat-free mass requires 1.8 kcal for each gram of fat free mass gain ($2000 \text{ grams} \times 1.8 \text{ kcal/gram} = +3,600 \text{ kcal}$). The loss of 2.7 kg of fat mass releases 9.3 kcal for each gram of fat lost ($2700 \text{ grams} \times 9.3 \text{ kcal/gram} = -25,110 \text{ kcals}$). This example (2 kg of fat-free mass gain and 2.7 kg of fat mass loss) would result in an estimate of a total loss of 21,510 kcal/person (kcals of fat lost subtracted from kcals of muscle gained, summarized in Table 1). Since the total increase in energy expenditure was only $\approx 20,930$ kcal it appears that the participants in this resistance training study did not increase their dietary intake to compensate for the added energy expenditure. It should be noted that even if the TEE increased +230 kcal/day the day after the first workout (highly unlikely) the total cumulative increase in energy expenditure across the 182 days of the study would have been 41,860 kcal creating an estimate of about 49% of the energy lost during dieting. So the estimate of compensation for this study would be between 0 and 49% (dependent on the average daily caloric deficit across the 182 days) of the increased energy expenditure. On the other hand, typical fat mass loss is normally approximately 2 kg with aerobic training with little change in fat-free mass (Table 1 illustrates the total loss in kcals within the body can be lower aerobic training than with an equivalent amount of resistance training). This translates into a dietary compensation for aerobic training of approximately 30% of increased energy expenditure [18].

Increase in TEE with Training

Despite relatively large energy expenditures during aerobic exercise compared to resistance exercise, resistance training may induce a larger increase in TEE than aerobic training.

Resistance training typically increases REE +7–8%, most likely from gains in muscle hypertrophy [5]. Chronic aerobic training produces only minimal increases in REE, although we have shown that REE can increase +5–8% for 24 hours following a bout of relatively high-intensity aerobic exercise [19;20]. It is possible that individuals might decrease physical activity and NEAT in response to vigorous aerobic exercise training. Indeed this has been shown to occur in several studies in which untrained individuals performed relatively high-intensity, high-volume exercise training [21–26]. The reasons for this decrease have yet to be fully explained; however, it is possible that increased fatigue due to frequent training results in less NEAT. One of the most cited examples of reduced NEAT (–231 kcal/day) occurring in response to chronic aerobic training was shown in a cohort of older adults performing high-intensity (70% $\text{VO}_{2\text{max}}$), and high frequency (5 times/week) exercise for 10 weeks [23]. Given the relatively short training period, it is possible these older adults had not adapted to such an extreme training regimen and thus, felt fatigued which resulted in participation in less free-living physical activity. Entirely different results may have occurred if a lower intensity, less frequent, and/or longer adjustment period had been used.

The hypotheses that over-reaching/overtraining (syndrome characterized by excessive training leading to impairment in physical performance) may negatively affect participation in physical activity and NEAT is further supported by a recent study designed to evaluate the effects of different frequencies of combined aerobic and resistance training [9]. A group of older women who performed intense aerobic exercise (80% peak heart rate for 40 minutes/session) and resistance exercise (2 sets of 10 exercises at 80% 1 RM) 3 times/week decreased NEAT 150 kcal/day after 16 weeks of training. Conversely, a group of older women who followed the same daily training regimen, who instead exercised just 2 times/week increased NEAT +200 kcal/day leading to an overall significant increase in total energy expenditure of ≈ 300 kcal/day [9].

Accordingly, resistance exercise may be a better mode of training for influencing NEAT [27], especially very high-intensity interval resistance training [28]. In a recent study Paoli et al. [28] showed that 31 minutes of high-intensity interval resistance training increased REE over 400 kcal/day 22 hours after exercise compared to about ≈ 100 kcal/day of 60 minutes of traditional resistance training. In this study, exceptionally high blood lactate levels (>10 mmol/L) following the high-intensity interval resistance training were used to verify the intensity of this kind of training. While this mode of exercise leads to robust increases in REE, the long term effects of this mode of training on metabolic health and physiological parameters of fitness has yet to be determined.

Ease of movement (as defined by reduced heart rate, ventilation, energy cost of locomotion, and perceived effort during standardized tasks) is positively related to NEAT [29;30]. Moreover, resistance training-induced increases in strength are positively related to increased locomotion economy [31] and ease of movement [32] and are even more strongly related than aerobic fitness [5], most likely because tasks performed during day-to-day activities are of relatively short duration or moderate to low-intensity, thus not significantly challenging the aerobic system [5].

It is often thought that exercise economy should be inversely related to NEAT since the energy cost for doing any task would be reduced. However, research by our group has not supported this assertion. Instead, NEAT actually seems to be enhanced in those individuals who have increased locomotion economy [29]. In addition, perceived exertion while walking at 4.84 kilometers/hour (3 mph) adjusted for physiological effort after weight loss is related to increased weight gain one year following weight loss, as well as decreased participation in aerobic exercise training [33]. Work from our lab shows that muscle metabolic economy of the triceps surae muscle measured during 45% maximum isometric plantar flexion, whole body maximal oxygen uptake, and quadriceps strength were all independently related to reduced weight gain [34]. As such, these data demonstrate that ease of movement may contribute to the ability to maintain weight [34]. The only logical explanation for increases in exercise economy coinciding with increased NEAT would be that increases in economy are associated with the inclination to be more physically active. Consistent with this hypothesis, we have recently shown that NEAT is significantly related to walking ease [29]. In addition, AEE adjusted for treadmill walking, stair climbing, cycling, carrying groceries energy cost/minute (an index of physical activity that adjusts for body size and exercise economy of different individuals) is increased following weight loss in women who resistance trained while this was unchanged in women who were aerobically trained or did not exercise train [29]. Although the cited research support the notion that improved ease of movement (decreased heart rate and perception of effort for any task) translate to increased participation in NEAT, we recognize that the decision to be physically active is a complicated matter, controlled by higher centers of the brain, including the hypothalamus [35]. A number of different neuro-mediators likely influence NEAT including orexin, ghrelin, and agouti gene-related protein [36]. At this time it is unclear whether increased fitness and ease in locomotion influence NEAT through neuro-mediators or independent of neuro-mediators.

Perhaps the best means for increasing TEE is through a combination of aerobic and resistance training. Energy expenditure is increased dramatically during an aerobic exercise bout. Most relatively fit individuals can sustain energy expenditures of ≈ 8 – 14 kcal/minute or ≈ 480 – 840 kcal/hour, depending on body size and aerobic capacity. The energy expenditure during resistance exercise is much lower, averaging between ≈ 2 and ≈ 8 kcal/minute or ≈ 120 – 480 kcal/hour. The estimated increase in TEE with a combined aerobic and resistance training regimen (alternating days) of only 30 minutes a day is shown in Table 2, demonstrating the total cumulative effect of exercise training of ≈ 650 kcal/day. This example underscores the potential benefit of a combined training program of aerobic and resistance exercise as opposed to one or the other, which is feasible for most individuals and not a bad investment in trying to achieve energy balance for only 30 minutes of work/day.

Exercise Training and Weight Gain

Due to methodological challenges, few research studies have examined the effects of exercise training on weight gain over an extended period of time. First, yearly weight gain is relatively small for most adults, highlighting the need for interventions to extend over longer time periods, perhaps 5 or 10 years, and/or larger sample sizes. To compound the problem, home-based interventions that are much easier for subjects to participate in, generally yield

rather poor results due to low adherence to sufficiently “high” intensity and volume of training. One way relatively large weight gains can be studied over shorter time periods is to evaluate individuals after they have lost weight. Weight regain of 40–60% of weight lost are normally experienced during the first year following weight losses of ≈ 10 –15% of body weight. Using this weight loss model, we prescribed weight loss of $\approx 15\%$ (≈ 12 kg) from initial body weight in a cohort of 97 overweight premenopausal women. For one year following weight loss, all participants were offered monthly classes on weight maintenance. In addition, 32 women were randomly assigned to aerobic training twice/week, 35 women were randomly assigned to resistance training twice/week, and 30 women were randomly assigned to no formalized exercise training. Adherence to the exercise training was quite variable among this cohort. Thus, in order to measure the effects of exercise adherence on weight maintenance, women were categorized according to adherence (defined as having completed at least 60% of scheduled training) or non-adherence groups (defined as having completed less than 60% of scheduled training). We found that the aerobic training adherence group gained 3.1 kg (25% of weight lost) and the resistance trained adherence group gained 3.9 kg (32% of weight lost) while the non-exercisers and non-adherers to the exercise training gained an average of 6.5 kg (54% of weight lost). Perhaps the most significant finding in this study was that both exercise groups that adhered to training did not regain visceral fat for one year following weight loss, while the non-adherers and non-exercisers regained $\approx 50\%$ of the visceral fat they lost [37]. These results show that high-intensity exercise training not only slows weight gain after weight loss, but prevents harmful visceral fat regain for one year following weight loss [37].

Additionally, exercise training may affect metabolic health independent of NEAT. Recently, it has been shown that high levels of cardiorespiratory fitness modify cardiovascular risk factor clustering so that the negative effects of sedentary behavior are abolished even when the recommended amounts of physical activity are not met [38]. In addition, substituting low intensity physical activity for sedentary behavior had a trivial effect on cardiovascular disease risk while risk of cardiovascular disease was decreased following substitution of sedentary behavior with moderate-to-vigorous physical activity [39].

Conclusion

Though sarcopenia will occur with advancing age, along with concomitant decreases in strength, aerobic fitness, ease of movement, energy expenditure and increased susceptibility of weight gain, high-intensity exercise training can slow the adverse effects. Indeed, it is possible for a highly fit 75 year old to have similar physiologic function of a 35 year old which will undoubtedly make it easier to maintain NEAT and TEE and reduce the propensity for weight gain. However, the key is intensity. Without at least a small amount of high-intensity training, the progressive loss of muscle, function, and weight gain will accelerate the deleterious effects of aging.

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Reference List

1. Baumgartner RN. Body composition in healthy aging. *Ann N Y Acad Sci.* 2000; 904:437–448. [PubMed: 10865787]
2. Morley JE, Baumgartner RN, Roubenoff R, Mayer J, Nair KS. Sarcopenia. *J Lab Clin Med.* 2001; 137:231–243. [PubMed: 11283518]
3. Baumgartner RN, Wayne SJ, Waters DL, Janssen I, Gallagher D, Morley JE. Sarcopenic obesity predicts instrumental activities of daily living disability in the elderly. *Obes Res.* 2004; 12:1995–2004. [PubMed: 15687401]
4. Lexell J. Human aging, muscle mass, and fiber type composition. *J Gerontol A Biol Sci Med Sci.* 1995; 50(Spec No):11–16. [PubMed: 7493202]
5. Hunter GR, McCarthy JP, Bamman MM. Effects of resistance training on older adults. *Sports Med.* 2004; 34(5):329–348. [PubMed: 15107011]
6. Bamman MM, Hill VJ, Adams GR, Haddad F, Wetzstein CJ, Gower BA, Ahmed A, Hunter GR. Gender differences in resistance-training-induced myofiber hypertrophy among older adults. *J Gerontol A Biol Sci Med Sci.* 2003; 58(2):108–116. [PubMed: 12586847]
7. Poehlman ET, Aciero PJ, Goran MI. Endurance exercise in aging humans: Effects on energy metabolism. *Exerc Sport Sci Rev.* 1994; 22(1):251–271. [PubMed: 7925546]
8. Hunter GR, Weinsier RL, Gower BA, Wetzstein CJ. Age-related decrease in resting energy expenditure in sedentary white women: effects of regional differences in lean and fat mass. *American Journal Clin Nutr.* 2001; 73:333–337.
9. Hunter GR, Bickel CS, Fisher G, Neumeier W, McCarthy JP. Combined aerobic/strength training & energy expenditure in older women. *Med Sci Sports Exerc.* 2013; 45(7):1386–1393. [PubMed: 23774582]
10. Weinsier RL, Hunter GR, Desmond RA, Byrne NM, Zuckerman PA, Darnell BE. Free-living activity energy expenditure in women successful and unsuccessful at maintaining a normal body weight. *Am J Clin Nutr.* 2002; 75:499–504. [PubMed: 11864855]
11. Schoeller DA, Shay K, Kushner RF. How much physical activity is needed to minimize weight gain in previously obese women? *Am J Clin Nutr.* 1997; 66:551–556. [PubMed: 9280172]
12. Weinsier RL, Hunter GR, Gower BA, Schutz Y, Darnell BE, Zuckerman PA. Body fat distribution in white and black women: different patterns of intraabdominal and subcutaneous abdominal adipose tissue utilization with weight loss. *Am J Clin Nutr.* 2001; 74:631–636. [PubMed: 11684531]
13. Weinsier RL, Hunter GR, Zuckerman PA, Darnell BE. Low resting and sleeping energy expenditure and fat use do not contribute to obesity in women. *Obes Res.* 2003; 11(8):937–944. [PubMed: 12917497]
14. McCardle, WD., Katch, FL., Katch, VL. *Exercise Physiology : energy, nutrition, and human performance.* third. Philadelphia: Lea & Febiger; 1991.
15. Hunter GR, Wetzstein CJ, Fields DA, Brown A, Bamman MM. Resistance training increases total energy expenditure and free-living physical activity in older adults. *J Appl Physiol.* 2000; 89:977–984. [PubMed: 10956341]
16. Elbelt U, Hoffman I, Pirlich M, Strasburger CJ, Lochs H. Differences of energy expenditure and physical activity patterns in subjects with various degrees of obesity. *Clin Nutr.* 2010; 29:766–772.
17. Del Corral P, Chandler-Laney PC, Casazza K, Gower BA, Hunter GR. Effect of dietary adherence with or without exercise on weight loss: A mechanistic approach to a global problem. *J Clin Endocrinol Metab.* 2009; 94:1602–1607. [PubMed: 19258409]
18. King, NA. Behavioural compensation responses to exercise interventions: barriers to weight loss. In: Hills, AP, King, NA., Byrne, NM., editors. *Phys Act Obes.* first. Sidney: Queensland Government; 2006. p. 91-99.
19. Hunter GR, Byrne NM, Gower BA, Sirikul B, Hills AP. Increased resting energy expenditure after 40 minutes of aerobic but not resistance exercise. *Obesity.* 2006; 14(11):2018–2025. [PubMed: 17135619]
20. Treuth MS, Hunter GR, Williams M. Effects of exercise intensity on 24-h energy expenditure and substrate oxidation. *Med Sci Sports Exerc.* 1996; 28(9):1138–1143. [PubMed: 8883001]

21. Meijer EP, Westerterp KR, Verstappen FT. Effect of exercise training on total daily physical activity in elderly humans. *Eur J Appl Physiol.* 1999; 80(1):16–21.
22. Kempen PG, Saris HM, Westerterp KR. Energy balance during an 8-wk energy-restricted diet with and without exercise in obese women. *Am J Clin Nutr.* 1995; 62:722–729. [PubMed: 7572699]
23. Goran MI, Poehlman ET. Endurance training does not enhance total energy expenditure in healthy elderly persons. *Am J Physiol.* 1992; 263(5):E950–E957. [PubMed: 1443128]
24. Donnelly JE, Jacobsen DJ, Whately JE, Hill JO, Swift LL, Polk B, Tran ZV, Reed G. Nutrition and physical activity program to attenuate obesity and promote physical and metabolic fitness in elementary children. *Obes Res.* 1996; 4:229–243. [PubMed: 8732957]
25. Colley R, Byrne NM, Hills AP. Quantifying the effect of physical activity on total energy expenditure in obese women. *Obes Res.* 2005; 13:A24.
26. Blaak EE, Westerterp KR, Bar-or O, Wouters LJ, Saris WH. Effect of training on total energy expenditure and spontaneous activity in relation to training in obese boys. *Am J Clin Nutr.* 1992; 55(4):777–782. [PubMed: 1550058]
27. Paoli A, Moro T, Bianco A. Lift weights to fight overweight. *Clin Physiol Funct Imaging.* 2015; 35:1–6. [PubMed: 24612071]
28. Paoli A, Moro T, Marcolin G, Neri M, Bianco A, Palma A, Grimaldi K. High intensity interval resistance training (HIRT) influences resting energy expenditure and respiratory ratio in not-dieting individuals. *J Transl Med.* 2012; 10(237):1–8. [PubMed: 22214470]
29. Hunter GR, Fisher G, Neumeier WH, Carter SJ, Plaisance EP. Exercise training and energy expenditure following weight loss. *Med Sci Sports Exerc.* 2015; 47(9):1950–1957. [PubMed: 25606816]
30. Hunter GR, Weinsier RL, Zuckerman PA, Darnell BE. Aerobic fitness, physiologic difficulty and physical activity in Black and White women. *Int J Obes.* 2004; 28:1111–1117.
31. Hunter GR, McCarthy JP, Bryan DR, Zuckerman PA, Bamman MM, Byrne NM. Increased strength and decreased flexibility are related to reduced oxygen cost of walking. *Eur J Appl Physiol.* 2008; 104:895–901. [PubMed: 18758805]
32. Taaffe DR, Duret C, Wheller S, Marcus R. Once-weekly resistance exercise improves muscle strength and neuromuscular performance in older adults. *J Am Geriatr Soc.* 1999; 47(10):1208–1214. [PubMed: 10522954]
33. Brock DW, Chandler-Laney P, Alvarez JA, Gower BA, Gaesser GA, Hunter GR. Perception of exercise difficulty predicts weight regain in formerly overweight women. *Obesity.* 2010; 18:986–991.
34. Larew K, Hunter GR, Larson-Meyer EE, Newcomer BR, McCarthy JP, Weinsier RL. Muscle metabolic function, exercise performance, and weight gain. *Med Sci Sports Exerc.* 2003; 35:230–236. [PubMed: 12569210]
35. Kotz CM, Teske JA, Billington CJ. Neuroregulation of nonexercise activity thermogenesis and obesity resistance. *Am J Physiol.* 2008; 294(3):R699–R710.
36. Villablanca PA, Alegria JR, Mookadam F, Holmes DR, Wright RS, Levine JA. Nonexercise activity thermogenesis in Obesity Management. *Mayo Clinic Proceedings.* 2015; 90(4):509–519.
37. Hunter GR, Brock DW, Byrne NM, Chandler-Laney PC, Del-Correl PD, Gower BA. Exercise training prevents regain of visceral fat for 1 year following weight loss. *Obesity.* 2010; 18:690–695. [PubMed: 19816413]
38. Nauman J, Stensvold D, Coombes JS, Wisloff U. Cardiovascular fitness, sedentary time, and cardiovascular risk factor clustering. *Med Sci Sports Exerc.* 2016; 48(4):625–632. [PubMed: 26587846]
39. Wellburn S, Ryan CG, Azevedo LB, Ells L, Martin DJ, Atkinson G, Batternam AM. Displacing sedentary time: association with cardiovascular disease prevalence. *Med Sci Sports Exerc.* 2016; 48(4):641–647. [PubMed: 26559454]
40. Misra, A. Body fat and its relationship with metabolic syndrome indicators in the non-obese, overweight and obese. In: Hills, AP, King, NA., Byrne, NM., editors. *Physic Act Obes.* first. London, UK: Smith-Gordon Nishimura; 2006. p. 105–110.

Figure 1. Model for illustrating our hypothesis showing the impact of high intensity aerobic and resistance training on ease of locomotion, NEAT, risk of obesity, and metabolic health.

Figure 2.
Consequences of Sarcopenia.

Figure 3.

Individuals who maintained weight (average 0.5 kg further loss) for one year following a 10 kg weight loss had NEATs that were approximately ≈ 200 kcal/day higher than those who gained weight (average 9.0 kg gain) both prior to and after one year. (Adapted from reference 37, difference between gainers and maintainers, $p < 0.05$)

Comparison of energy lost during 4 months of aerobic versus 4 months of resistance training using data from King et al. [40] and Hunter et al. [15] and methods by Del Corral et al. [17].

Table 1

	^a FM	^a stored energy FM	^a FFM	^a stored energy FFM	^a Body Mass	^a Stored energy Body Mass
4 Months Aerobic Training	-2.0 kg	-18,600 kcal	0	0	-2.0 kg	-18,600 kcal
4 Months Resistance Training	-2.7 kg	-25,110 kcal	+2.0 kg	+3,600 kcal	-0.7 kg	-21,510 kcal

Table 2

Potential increase in daily energy expenditure consequent to participation in either 30 minutes of low/moderate intensity versus high intensity aerobic and resistance training on alternate days, i.e. 30 minutes of aerobic and 30 minutes of resistance on alternate days.

Variables	Low-Intensity		High-Intensity	
	Mechanism	(+)EE Above Normal (kcal/day)	Modality (Mechanism)	(+)EE Above Normal (kcal/day)
Resting EE	N/A	N/A	➤ <u>Acute Phase (+)</u> Aerobic Exercise (Energy Resynthesis; Catecholamines; Body Heat) ➤ <u>Chronic Phase (+)</u> Resistance Exercise (Skeletal Muscle Hypertrophy)	Acute Phase (+50–150) Chronic Phase (+50–150)
30 Minutes Exercise EE	ATP Synthesis	Aerobic Exercise (+100–150) Resistance Exercise (+50–100)	ATP Synthesis	Aerobic Exercise (+200–400) Resistance Exercise (+50–200)
Non-Exercise Activity Thermogenesis	Unknown	+0–50	➤ Aerobic Exercise (Heart Rate Recovery; Rate-Pressure Product) ➤ Resistance Exercise (Ease of Movement)	Aerobic Exercise (+0–150) Resistance Exercise (+50–250)
Total EE		+150		+850