

General Sports Participation rather than Amount or Intensity is Related to Body Composition among Healthy Adolescents

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Abstract Cross sectional and cohort studies on the relationship between physical activity (PA) and body composition reveal conflicting results that range from “no” to “moderate” effects. However, randomized trial studies show that PA affects body composition with relevant effect sizes if a) energy intake is controlled or b) amount of PA is very high. The aim of this study was to determine the relationship between PA and body composition in a cross sectional sample by differentiating across general sports participation, amount, intensity and types of PA. 148 young adults (44 females, 104 males; age: 23.5 years) from a German student population completed a testing battery involving a standardized physical activity questionnaire and anthropometric measurements to assess BMI, waist-to-hip ratio and body fat percentage (BF%) using air-displacement plethysmography. Active subjects revealed a lower BF% ($p < .01$; males: $\Delta = 2.3\%$, females: $\Delta = 4.6\%$) than inactive ones. Work-related physical activity was positively correlated with BF% ($r_{\text{part}} = .54$) and had to be excluded from total PA to uncover a significant negative correlation between total PA and BF% ($r_{\text{part}} = -.21$). The results indicate the necessity to assess the type of PA in order to find small to moderate effects on body composition in collectives. We suggest that the expected negative correlation between PA and body fat only occurs if PA is linked to other factors regarding a healthy lifestyle like a balanced diet or performance and/or weight-loss oriented exercise. This could be the missing link between effect sizes in observational studies among broad collectives and performance and/or weight-loss oriented randomized trial experiments.

Keywords Physical Activity, Body Composition, Air-Displacement Plethysmography, Young Adults, Body Fat

1. Introduction

The increasing prevalence of overweight and obesity among all age groups in developed countries is of growing concern[1-3], making it one of the most important health related issues of the 21st century[4]. This trend is paralleled by a continuous decrease in regular physical activity among both the elderly[5], and particularly the young population[6]. Given that both, physical inactivity and obesity have been considered as two independent risk factors of morbidity and mortality rates of associated metabolic and cardiovascular disorders[7], neurological disorders and even certain types of cancer[8], there is growing interest in the understanding between physical activity (PA) and body composition.

Remarkably, neither increased energy expenditure necessarily leads to weight-loss nor low basal metabolic rate leads inevitably to obesity[9]. Thus, the relationship between PA and body composition seems less clear than widely believed.

A meta-analysis performed by Rowlands, Ingledew & Eston [10] found a small to moderate relationship between body fat and PA in children. However, in recent studies the reported associations are still contradictory, with some finding neither relations for children nor for adolescents[11],[12] while others have observed low correlations[13],[14] or gender dependent relations[15],[16]. The lack of finding correlation is often explained by the methods used to assess PA. Using a questionnaire, PA variables tend to have low validity and reliability[17]. But even if objective methods are used to assess activity, the relationship is not clarified yet[18]. An alternative explanation for these controversial findings could be the complex structure of PA itself. For example, studies that assess work-related activity fail in finding a positive influence on body composition and health factors[19],[20]. This may be an indication that in addition to amount and intensity, the type of PA is very important to uncover its effect on body composition.

The main objective of the present cross-sectional study was therefore to investigate which domains of PA in terms of (i) general sports participation, i.e. inactive vs. active, (ii) amount, (iii) intensity and (iv) type of activity i.e. sports activity, habitual activity and work-related activity impact

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body composition and related anthropometric indices in young adults.

2. Research Methods

2.1. Study Sample and Design

The data presented in this paper were gathered as a part of a prospective cross-sectional study to determine the relation ship between physical (in-) activity, brain function and cognitive performance in young adulthood. 148 young adults (44 females, 104 males) were recruited from the student population at a German university between April 2010 and June 2011. Inclusion criteria for participation in the study were a qualification for university entrance and at least 12 months of physical activity or inactivity, respectively. Exclusion criteria comprised excessive alcohol consumption or smoking, acute or chronic neurological, psychiatric or medical diseases, any medications affecting the central nervous system and inability to exercise at least 10 minutes.

Before being invited to the body composition testing day at the institute's exercise physiology laboratory, participants completed an online questionnaire to report their physical activity habits. After the study's procedures and risks were explained, participants gave their written informed consent. This study was approved by the ethics committee of the State Chamber of Physicians of Baden-Wuerttemberg (Germany).

2.2. Measures

2.2.1. Physical Activity Assessment

All participants completed a standardized online physical activity questionnaire to declare whether they were athletes or non-athletes (*General sports participation*).

Furthermore, athletes were asked to report type, duration, frequency and intensity of exercise. Based on these questions, which were assessed separately for winter and summer season, the overall exercise induced energy expenditure (kcal/week) was calculated (*Sports activity*, SA). The formula consisted of the stated minutes per week multiplied by the average energy expenditure per minute (MET) regarding the type of sport[21] and weight: $Kcal_{SA} = min * kg * MET$. In addition, participants were asked about their average time spent walking or cycling during a regular week (*Habitual*

physical activity, HA). The formula for assessing HA comprised the minutes spent per week multiplied with 3.5 MET*weight. *Work-related physical activity* (WRA) was assessed with a question on weekly minutes being physically active with medium or high intensity at work multiplied with an average of 5.0 MET*weight according to Ainsworth et al.[21]. To clarify the role of exercise intensity, participants were divided into a MPA (low to moderate sports activity) and a VPA (vigorous sports activity) group based on their answers to the question (3-scaled) about average exercise intensity.

2.2.2. Anthropometric Measurements

For the anthropometric measurements, participants were barefooted and wore form-fitting underwear or swimsuits. They had their height, waist and hip circumferences measured by two experienced investigators using a stadiometer and a plastic tape measure. Body Mass Index (BMI) and Waist-to-Hip Ratio (WHR) were calculated from the obtained data. Subsequently, body mass and body composition were measured via air-displacement plethysmography using a BOD POD Gold Standard® System (Life Measurement Inc., USA; now: COSMED, Italy). The BOD POD utilizes the principles of whole body densitometry to estimate percentage and absolute amount of fat and body lean mass and was proved to be a reliable and valid method for estimating body fat in a heterogeneous sample of adults[22].

2.3. Statistical Analysis

Data are reported as means and standard deviations. Differences in body composition between groups (general sports activity status / intensity of activity) were tested for statistical significance using one-way analysis of covariance with age and gender as covariates. Multiple linear regression adjusted for age and sex was employed to assess the relation between the amount of PA and body composition measures. Partial correlation coefficients are reported. Residuals did not violate the assumption of multiple linear regression modeling. All statistical analysis was performed using SPSS Statistics 19.0. The level of significance was set at $p < 0.05$ for all testing. The data set showed no missing data. All discussed outcome variables were assessed for all participants.

Table 1. Mean \pm SD values for participant demographic, body composition and PA data

Variable	All participants	Females	Males
N	148	44	104
Age (years)	23.5 \pm 3.0	22.7 \pm 2.6	23.8 \pm 3.1
Body Fat (%) ¹	19.0 \pm 8.4	28.3 \pm 6.8	15.2 \pm 5.5
Body Fat (kg)	13.2 \pm 5.9	17.5 \pm 6.0	11.4 \pm 4.7
BMI (kg/m ²)	22.6 \pm 2.2	22.2 \pm 2.4	22.8 \pm 2.0
Waist to Hip-Ratio	0.82 \pm 0.07	0.76 \pm 0.06	0.85 \pm 0.06
Total PA (kcal/week)	3292.0 \pm 2518.4	3011.2 \pm 2811.2	3414.5 \pm 2386.8
SA (kcal/week)	2256.2 \pm 1910.1	1599.9 \pm 1545.3	2533.8 \pm 1987.1
HA (kcal/week)	632.5 \pm 432.2	641.5 \pm 378.0	628.7 \pm 455.1
WRA (kcal/week)	409.4 \pm 1305.8	769.9 \pm 1844.2	255.4 \pm 962.7

¹ Body Fat % and kg = measured with BOD POD Gold Standard air-displacement plethysmography

3. Results

3.1. General Trends

Demographic and physical activity data for all participants are provided in **Table 1**.

Men had a lower absolute and relative amount of body fat than women ($p < 0.05$, $\eta^2 = 0.235$ and $p < 0.05$, $\eta^2 = 0.511$). Furthermore, men had a higher Waist to Hip-Ratio compared to women ($p < 0.05$, $\eta^2 = 0.277$). No significant difference was observed for BMI between men and women ($p = 0.09$, $\eta^2 = 0.020$).

A significant age effect was found for WHR, showing a higher ratio with increasing age ($p < 0.05$, $\eta^2 = 0.035$). BMI ($p = 0.11$, $\eta^2 = 0.018$), fat percentage ($p = 0.67$, $\eta^2 = 0.001$) and absolute amount of fat ($p = 0.66$, $\eta^2 = 0.001$) were not significantly affected by age.

3.2. Body Composition and General Sports Participation

Differences between general sports participation, i.e. inactive vs. active in body composition are given in **Table 2**.

Irrespective of age and gender, active participants had a significantly lower percentage and absolute amount of body fat than inactive ones. However, no differences could be observed for BMI and WHR between active and inactive participants.

3.3. Body Composition and Amount of Activity

Correlation coefficients between the amount of activity with respect to sports activity (SA), habitual activity (HA) and work-related activity (WRA) and body composition are provided in **Table 3**.

After adjusting for age and gender, neither the amount of sports nor habitual activity was significantly related to any body composition measure except for BMI, which showed a small and significant correlation to SA. Furthermore, no

significant relationship could be detected between total amount of PA and body composition.

Interestingly, WRA was moderately and significantly related to absolute body fat mass (**Figure 1a**). Since this relationship was positive, indicating a higher fat mass with increasing WRA, the relationship between PA and body fat was re-analyzed by correcting for the influence of WRA. Excluding WRA from total PA lead to a significant negative correlation ($r = -.21$) with body fat percentage (**Figure 1b**).

3.4. Body Composition and Intensity of Activity

Participants who report to exercise with moderate intensity showed a BMI of 22.1 ± 1.8 , participants performing with higher intensity showed a BMI of 23.2 ± 2.1 ($F = 7.5$; $p < .01$; $\eta^2 = .06$). After adjusting for age and sex, amount of fat was not significantly ($F = .51$; $p < .48$; $\eta^2 = .01$) lower in the group of people exercising with vigorous activity (12.3 ± 5.2 kg body fat) than among participants exercising with moderate activity (12.5 ± 5.1 kg body fat).

The correlations for total amount of SA in kcal and body composition differed between participants performing medium and high intensity exercise is summarized in the bottom column of **Table 3**.

There were no associations between SA and BOD POD fat percentage and total fat mass in both intensity groups. A significant positive correlation was found between SA and BMI within the vigorous intensity group. Further, a negative correlation between PA and WHR could be detected within the moderate intensity group.

4. Discussion

4.1. Major Findings

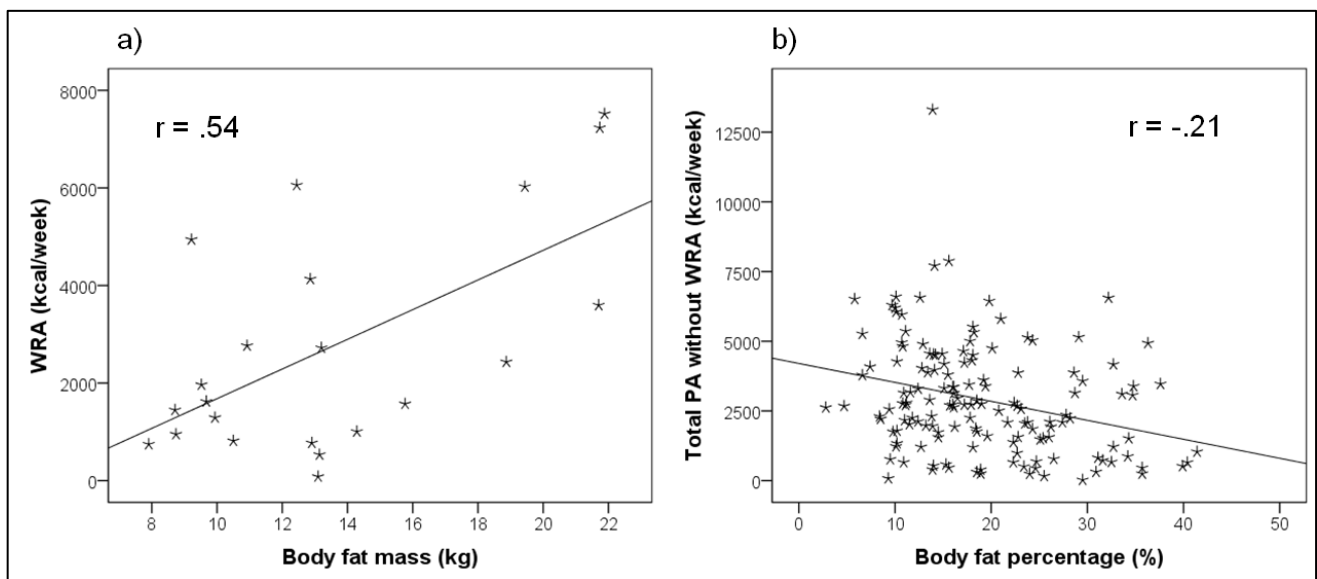


Figure 1. Association between body fat mass and work related activity per week (a) and between body fat percentage assessed via air-displacement plethysmography and total physical activity per week without work related activity (b). Linear trend symbolized by drawn line. Each mark represents one participant

Table 2. Gender-separated differences between active and inactive participants in body composition and ANCOVA adjusted for age and sex

		BOD POD (%)		BOD POD (kg)		BMI		WHR	
		Active ²	Inactive	Active	Inactive	Active	Inactive	Active	Inactive
Males ¹		14.8	17.1	11.1	13.0	22.8	22.8	0.84	0.86
		±5.2	±6.6	±4.3	±6.5	±1.8	±3.0	±0.06	±0.05
Females		26.7	31.3	16.4	19.8	21.9	22.6	0.77	0.75
		±6.3	±7.0	±5.4	±6.7	±2.3	±2.7	±0.05	±0.07
F		8.20		6.66		.45		.00	
ANCOVA	p	<.01		.01		.50		.98	
	η ²	.054		.044		.003		.000	

¹Sample sizes: Active: n=117, Inactive: n=31; Males: n=104, Females: N=44.²General sports activity was assessed by the question "Are you physically active – Yes or No"**Table 3.** Correlations r_{part} (adjusted for age and sex) between body composition and amount of activity

	BOD POD fat % (p Value)	BOD POD fat kg (p Value)	BMI (p Value)	WHR (p Value)
SA ¹ (n=117)	-.11 (.24)	-.06 (.56)	.18* (.05)	-.05 (.58)
HA ¹ (n=147)	-.04 (.66)	-.00 (.98)	.06 (.50)	-.10 (.24)
WRA ¹ (n=22 ²)	.33 (.16)	.54* (.01)	.38 (.10)	-.21 (.37)
TotalPA ¹ (n=147)	-.14 (.09)	-.10 (.23)	.05 (.58)	-.03 (.71)
TotalPA without WRA (n=147)	-.21* (.01)	-.16 (.06)	.08 (.32)	-.06 (.48)
MPA ³ (n=66)	-.14 (.26)	-.10 (.44)	-.04 (.77)	-.25* (.05)
VPA ³ (n=51)	-.08 (.59)	-.01 (.93)	.31* (.03)	.08 (.61)

¹SA= Sports activity; HA= Habitual activity; WRA= Work-related physical activity; Total PA: Physical activity (SA+HA+WRA)²Among 147 participants, only 22 reported work related activity³MPA: Amount of SA from those participants who exercised with moderate intensity, VPA: with vigorous intensity

The present study shows that neither amount nor intensity of PA/SA is a good predictor for body composition in young adults. Only a slight correlation between total PA and fat percentage could be found after excluding WRA. WRA showed a positive correlation with body fat, indicating that participants with higher WRA had higher body fat. SA itself showed only numerically low, non-significant associations with body fat.

Finally, general sports activity as indicated by the simple distinction between active and inactive participants was a significant predictor for body fat percentage as well as absolute amount of body fat and explained 5.4% and 4.4% of variance, respectively. Active men showed 2.3% less body fat than inactive, active females showed 4.6% less body fat than inactive.

4.2. Comparison with Previous Research & Possible Explanations

Tremblay et al.[23] investigated 1366 women and 1257 men as part of the 1981 Canada Fitness Survey and found that subjects engaging in the most intense forms of exercise had the lowest skinfolds and waist-to-hip ratios. These effects remained significant after controlling for total energy expenditure and leisure time activity and are supported by recent literature[24]. Thus, the finding of the present study that neither SA itself nor exercise intensity revealed a significant impact on body composition seems puzzling. A striking difference between the Canadian Fitness Survey and the present study pertains to sample size and characteristics.

While Tremblay et al. were able to investigate extreme groups, the present sample can be considered as typical within a group of students at a technical university with regard to the distribution of gender, age and general physical activity status. It is a rather homogenous group of young, healthy adults compared to more representative samples including different age groups and various professional and social backgrounds. The power to detect any significant relationships with regard to SA and intensity might therefore be jeopardized by relatively narrow ranges in outcome measures. Aside statistical significance, the numerical data of the present study constantly show negative correlations between SA, HA, MPA, VPA and body composition variables. The significant correlation between BMI and VPA, indicating higher BMI values for people participating in physically intense activities, can be explained by an increased muscle mass associated with high-intensity exercise among already active participants.

There is no dispute about the fact that PA leads to an increase in energy expenditure which should in turn lead to an inverse relationship between PA and body fat percentage. Randomized, controlled trial studies show this unequivocally for SA if energy intake is controlled[25] or amount of exercise is very high[26]. Problems with finding this relationship in cross-sectionally assessed collective studies are mostly explained by methodological issues and expected effect sizes. When PA is measured objectively by using accelerometers, the results are mainly consistent, but reveal low effect sizes[13],[14]. In the present study we could show, that a

closer look at the type of activity is necessary to find this relation when using self-reported PA. Without excluding WRA, no association could be found in the data. After excluding WRA, the correlation coefficient of $r = -.21$ fits into the range of effect sizes previously reported in the studies mentioned above. This can be explained by the positive correlation between WRA and fat percentage. Though this finding may seem unexpected, it is in line with previous studies, failing to find a positive influence of WRA on body composition and health[20]. Data from Gutierrez-Fijis et al.[19] also showed that a higher amount of WRA is numerically associated with adiposity parameters. In their study, 11.5% of women who report intense work-related PA were obese, but only 5.9% of those who report no WRA. The numbers are 9.2% vs. 7.7% for men, respectively. We conclude that a closer look at the type of PA that leads to increased total energy expenditure (TEE) is needed to evaluate its effect on body composition. In a recent study by Pontzer et al.[27] they compared TEE of traditionally living Hadza hunter-gatherers with western adults. No differences in TEE could be found after controlling for weight. Nevertheless, Hadza hunter-gatherers showed significantly lower BF%. In addition they used TEE and basal metabolic rate to estimate physical activity level. A higher physical activity level was not significantly but numerically positively correlated with higher body fat percentage in their western sample. This outcome is exactly what we expect if physical activity level is calculated from TEE with no regard for the type of PA. Or in other words: Without excluding WRA from TEE.

We do not suggest that the inverse relationship between WRA and body fat percentage is founded in an inverse causality structure between body composition and the activity itself. More likely energy expenditure which is not linked to any health relevant intentions is compensated by an increase in energy intake and therefore loses its impact on body composition. Looking from a more elemental point of view it seems logical that frequent PA like WRA has to be compensated by a genetically disposed increase in energy intake to avoid long-term negative energy balances. This is in line with reports from controlled trial studies like the one from Ross et al.[25] reporting an increased energy intake in already obese men who exercise without the intention of losing weight. Whereas it is very likely that the amount of WRA might vary from time to time, habitual energy intake is much more stable. Once increased, it is very hard to lower it in time periods after or between weeks with high amounts of WRA. Pihl & Jürimäe[28] report that former top athletes who remained physically passive after their sporting career was discontinued, gained an average of 10.2 kg body weight throughout a duration of 15 to 40. Other factors like social status associated with physically intense occupational work could of course also add up for these findings. Nevertheless, all forms of activities can only explain a small amount of variance in body fat. The explaining factor for total body fat is the ratio between total energy intake (TEI) and TEE[29].

Whereas TEI is defined by dietary habits, TEE is mostly defined by the resting metabolic rate and the so-called non-exercise activity thermogenesis NEAT[30],[31]. As previously reported by Levine[30], the majority of people engaging in sports exercise less than 2 hours per week and the additional activity-related energy expenditure [EAT] only accounts for about 100 kcal per day. Trial studies show that it is nearly impossible to lose a significant amount of weight with these small amounts of EAT only[25]. Recent studies suggest that a major cause for obesity could be related to the uncoupling of cell respiration by brown adipose tissue (BAT)[32],[33]. With increasing amount of BAT, individuals show a higher amount of NEAT, which effectively increases metabolic rate. While regular physical activity might have a potential beneficial effect on BAT and its activation[34], it is mostly defined by genetics, gender and age[35] and therefore PA itself only accounts for a small amount of the variance in body composition.

Interestingly, the simple question "Are you physically active?" turned out to be a good predictor for body fat percentage and amount. One could conclude that it is more important to know whether one calls himself active than to know the exact amount or intensity of PA in order to estimate body fat. However, BMI could not be explained by general PA. BMI simply reflects the ratio between body weight to height and does not differentiate between body fat and fat free mass which tends to be higher in active people.

We suggest that the question "Are you physically active?" not only reflects the existence or abstinence of PA, but also separates people by their general attitude towards a healthy and active way of life. Therefore the answer is linked to many other factors like nutrition or sedentary lifestyle which in sum explain the difference in body composition between active and inactive people. Especially in older collectives it also differentiates between those who are unable to participate in SA for health reasons and those who are able to. Future research is clearly needed to reveal the underlying factors that determine the answer to the question "are you physically active?"

4.3. Limitations of the Study

It should be noted that the present study is certainly limited by its cross-sectional nature and we do not intend to infer causality from our results. Furthermore, PA was assessed by a self-report and energy expenditure per week was estimated from different items of the questionnaire. This method has various limitations including recall bias and social-desirability. Measuring PA by objective methods such as accelerometers is more accurate but is always limited to a short time interval. Using a questionnaire offered the chance to assess different types of exercise as well as other PA parameter like amount and intensity of exercise in detail within one year prior to the study.

Another limitation of our study is the sample, which is only representative for a student population and pictures a very homogenous group of young, healthy and physically

active students at a German university. However, the study population is known to be typical within a group of students at a technical university in relation to gender and age distribution as well as percentage of physically active and inactive participants, respectively.

4.4. Conclusions

We do not want to question the fact that PA has positive effects on several health parameters or that PA leads to an increase in energy expenditure, which should consequently lead to an inverse relationship between all types of PA and body fat percentage. However, whereas SA shows only small effect sizes, some types of PA like WRA show no positive influence on body composition in collectives at all. It is suggested that this is explained by small amounts of burned calories plus the compensation by an equivalent increase in energy intake when PA is not linked to weight loss or performance related intentions. That means on the one hand it is very hard to add up a substantial amount of burned calories with normal amounts of work out, e.g. jogging 90 minutes a week. And on the other hand, every day activity like having a physically intense occupation is compensated by a genetically regulated increased food intake to avoid potentially destructive long term negative energy balances.

Finally, we found the simple participants' rating differentiating an active and inactive lifestyle to have the strongest impact on body composition. We conclude that factors which come along with the feeling of being active like an active lifestyle and a balanced diet are more important in maintaining a healthy body composition than exercise-associated thermogenesis (EAT) itself. Therefore future interventions should not only aim at increasing SA itself, but also foster a general healthy lifestyle considering dietary habits and sedentary behaviour, leading to subjective long-term perception as being physically active.

5. Author Disclosure Statement

The authors declare no competing or conflicting interests. This study was approved by the ethics committee of the State Chamber of Physicians of Baden-Wuerttemberg (Germany) and supported by a Grant from the Karlsruhe Institute of Technology.

REFERENCES

- [1] Knuth AG, Hallal PC. Temporal Trends in Physical activity: A systematic Review. *J Phys Act Health* 2009;6:548-59.
- [2] Singh GK, Kogan MD, Van Dyck PC. Changes in States-Specific Childhood Obesity and Overweight Prevalence in the United States from 2003 to 2007. *Arch Ped Adolesc Med* 2010;164:598-607.
- [3] Flegal KM, Carrol MD, Kit BK, Ogden CL. Prevalence of Obesity and Trends in the Distribution of Body Mass Index Among US Adults, 1999-2010. *JAMA* 2012;307:491-97.
- [4] Lobstein T, Baur L, Uauy R. Obesity in children and young people: A crisis in public health. Report of the International Obesity Task Force Childhood Obesity Working Group. *Obes Rev* 2004;5:5-104.
- [5] Hollmann W, Strüder HK, Tagarakis CVM, King G. Physical activity and the elderly. *Eur J Prev Card* 2007;14:730-39.
- [6] McCracken M, Jiles R, Blanck HM. Health Behaviours of the Young Adult U.S. Population: Behavioral Risk Factor Surveillance System, 2003. *Prev Chronic Dis* [serial online] 2007;4:A25. Internet <http://www.ncbi.nlm.nih.gov/pmc/articles/PMC1893124/> (accessed 17 July 2012).
- [7] Dijk SB, Takken T, Prinsen EC, Wittink H. Different anthropometric adiposity measures and their association with cardiovascular disease risk factors: a meta-analysis. *Neth Heart J* 2012;20:208-18.
- [8] Handschin C, Spiegelman BM. The role of exercise and PGC1alpha in inflammation and chronic disease. *Nature* 2008;454:463-69.
- [9] Hunter GR, Byrne NM. Physical activity and muscle function but not resting energy expenditure impact on weight gain. *J Str Cond Res* 2005;19:225-30.
- [10] Rowlands AV, Ingledew DK, Eston RG. The effect of type of physical activity measure on the relationship between body fatness and habitual physical activity in children: a meta-analysis. *Ann Hum Biol* 2000;27:479-97.
- [11] Ekelund U, Poortvliet E, Nilsson AY, Holmberg A, Sjöström M. Physical activity in relation to aerobic fitness and body fat in 14- to 15-year-old boys and girls. *Eur J Appl Physiol* 2001;85:195-201.
- [12] Ortega FB, Tresaco B, Ruiz JR, Moreno LA, Martin-Matillas M, Mesa JL, Warnberg J, Bueno M, Tercedor P, Gutiérrez A, Castillo MJ, the AVENA Study Group. Cardiorespiratory Fitness and Sedentary Activities Are Associated with Adiposity in Adolescents. *Obesity* 2007;15:1589-99.
- [13] Metcalf BS, Hosking J, Jeffery AN, Voss LD, Henley W, Wilkin TJ. Fatness leads to inactivity, but inactivity does not lead to fatness: a longitudinal study in children (Early Bird 45). *Arch Dis Child* 2011;96:942-47.
- [14] Ness AR, Leary SD, Mattocks C. Objectively measured physical activity and fat mass in a large cohort study of children. *PLoS Med* 2007;4:e97. doi:10.1371/journal.pmed.0040097.
- [15] Hussey J, Bell C, Bennett K, O'Dwyer J & Gormley J. Relationship between the intensity of physical activity, inactivity, cardiorespiratory fitness and body composition in 7-10-year-old Dublin children. *Br J Sports Med* 2007;41:311-16.
- [16] Ara I, Moreno LA, Levia MT, Gutin B, Casajús A. Adiposity, Physical Activity and Physical Fitness Among Children From Aragón, Spain. *Obesity* 2007;15:1918-24.
- [17] Farias JJC, Lopes AS, Florindo AA, Hallal PC. Validity and reliability of self-report instruments for measuring physical activity in adolescents: a systematic review. *Cad Saúde Pública* 2010;26:1669-91.
- [18] Ortega FB, Ruiz JR, Hurtig-Wennläf A, Vicente-Rodriguez

- G, Rizzo NS, Castillo MJ, Sjöström M. Cardiovascular fitness modifies the associations between physical activity and abdominal adiposity in children and adolescents: the European Youth Heart Study. *Br J Sports Med* 2010;44:256-62.
- [19] Gutiérrez-Fijsac JL, Guallar-Castillón P, Díez-Gañán L, López García E, Banegas JR, Rodríguez Artalejo F. Work-related physical activity is not associated with body mass index and obesity. *Obes Res* 2002;10:270-76.
- [20] Halldin M, Rosell M, de Faire U, Hellánus ML. The metabolic syndrome: prevalence and association to leisure-time and work-related physical activity in 60-year-old men and women. *Nutr Met Card Dis* 2007;17:349-57.
- [21] Ainsworth BE, Haskell WL, Herrmann SD, Meckes N, Bassett DR, Tudor-Locke C, Greer JL, Vezina J, Whitt-Glover MC, Leon AS. 2011 Compendium of Physical Activities: A Second Update of Codes and MET Values. *Medicine and science in sports and exercise* 2011;43:1575-81.
- [22] Fields DA, Goran MI, McCrory MA. Body-composition assessment via air-displacement plethysmography in adults and children: a review. *Am J Clin Nutr* 2002;75:453-67.
- [23] Tremblay A, Després JP, Craig CL, Ferris B, Stephens T, Bouchard, C. Effect of intensity of physical activity on body fatness and fat distribution. *Am J Clin Nutr* 1990;51:153-157.
- [24] Boutcher SH. High-intensity intermittent exercise and fat loss. *Journal of obesity [serial online]* 2011;2011:868305. Internet: <http://www.hindawi.com/journals/jobes/2011/868305/> (accessed 17 July 2012).
- [25] Ross R, Dagnonge D, Jones PJH, Smith H, Paddags A, Hudson R & Janssen I. Reduction in Obesity and Related Comorbid Conditions after Diet-Induced Weight Loss or Exercise-Induced Weight Loss in Men. *Ann Intern Med* 2000;133:92-103.
- [26] Slentz CA; Duscha BD, Johnson JL, Ketchum K, Aiken LB, Samsa GP, Houmard JA, Bales CW, Kraus WE. Effects of the Amount of Exercise on Body Weight, Body Composition, and Measures of Central Obesity. *Arch Intern Med* 2004;164:31-39.
- [27] Pontzer H, Raichlen DA, Wood BM, Mabulla AZP, Racette, SB, Marlowe FW. Hunter-Gatherer Energetics and Human Obesity. *PLoS ONE* 2012;7:e40503. doi:10.1371/journal.pone.0040503.
- [28] Pihl, E, Jürimäe, T. Relationships between body weight change and cardiovascular disease risk factors in male former athletes. *Int J Obes* 2001;25:1057-1062.
- [29] Goran MI, Reynolds KD, Lindquist CH. Role of Physical Activity in the Prevention of Obesity in Children. *Int J Obes* 1999;23:18-33.
- [30] Snyder EE, Walts B, Perusse L, Chagon YC, Weisnagel SY, Rankinen T, Bouchard C. The Human Obesity Gen Map: The 2003 update. *Obesity Res* 2004;12:369-439.
- [31] Levine JA. Nonexercise activity thermogenesis – liberating the life-force. *J Int Med* 2007;262:273-87.
- [32] Hansen JC, Gilman AP, Odland JO. Is thermogenesis a significant causal factor in preventing the “globesity” epidemic? *Med Hyp* 2010;75:250-56.
- [33] Gesta S, Tseng Y, Kahn R. Developmental Origin of Fat: Tracking Obesity to Its Source. *Cell* 2007;131:241-56.
- [34] Alahmadi MA, Hills AP, King NA, Byrne NM. Exercise intensity influences nonexercise activity thermogenesis in overweight and obese adults. *Med Sci Sports Exerc* 2011;43:624-31.
- [35] Nedergaard J, Bengtsson T, Cannon B. Three years with adult human brown adipose tissue. *Ann N Y Acad Sci* 2010;1212:E20-E36.