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The relative importance of aerobic capacity, physical activity and body mass index in impaired glucose tolerance and Type 2 diabetes

Elisabeth Hansen[1,2]*, Bodil J. Landstad[3,4], Kjell T. Gundersen[2] and Sven Svebak[1]

[1]Department of Neuroscience, Norwegian University of Technology and Science, Trondheim, Norway; [2]Faculty of Education, North-Trøndelag University College, Steinkjer, Norway; [3]Levanger Hospital, North-Trøndelag Hospital Trust, Levanger, Norway; [4]Department of Health Sciences, Mid Sweden University, Sundsvall, Sweden

Abstract

Aim: To investigate the relative importance of aerobic capacity, physical activity and body mass index (BMI) for discriminating between people with Impaired Glucose Tolerance (IGT) or Type 2 diabetes and healthy controls.

Method: Variables included scores on estimated VO_2-max (ml/kg/min) by walking the UKK walking-test, responses to questions on self-reported physical activity and BMI.

Design: Participants were recruited into groups of IGT, Type 2 diabetes and healthy controls ($N = 64$). Statistical analyses were performed by multifactor ANOVA, bivariate correlations and logistic regression.

Result: Obesity, as indicated by BMI, was most evident in the IGT and Type 2 diabetes groups when jointly compared with the healthy controls ($p = 0.004$, OR ≥ 16.00). However, when separately compared with the healthy controls, BMI scores strongly discriminated between the IGT versus healthy controls but failed to distinguish between Type 2 diabetes and healthy controls. Scores for aerobic capacity and level of physical activity failed to distinguish between healthy controls and IGT as well as Type 2 diabetes status.

Conclusion: BMI was significantly associated with IGT whereas aerobic capacity and level of physical activity were not predictive of group status for IGT and Type 2 diabetes. The results indicated that primary health care should focus on all means for weight reduction, including physical activity and other life style changes, in order to prevent individuals from escalating into IGT in order to prevent risk of Type 2 diabetes.

Keywords: *Aerobic capacity; body weight; exercise level; hyperglycemia*

*Correspondence to: Elisabeth Hansen, Institutt for Nevromedisin, Det medisinske fakultet, NTNU, Postboks 8905, 7491 Trondheim, Norge. Email e.hansen@ntnu.no

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According to the International Diabetes Federation and others, impaired glucose tolerance (IGT) and Type 2 diabetes as well as hypertension and overweight are increasing health concerns and major challenges for current public health management (Alberti, Zimmet, & Shaw, 2007; Boursier, 2006; Rennie, Wells, McCaffrey, & Livingstone, 2006; Wild, Roglic, Green, Sicree, & King, 2004). Physical inactivity and increased body weight are expected to increase the prevalence of Type 2 diabetes in Europe from 3.5% to 4.75% over the next 25 years (Williams, Freedman, & Deci, 1998). There is a substantial body of evidence showing that lifestyle, including reduced physical activity, is of importance for developing obesity (Cederholm & Wibell, 1991; Rennie et al., 2006; Sigal, Kenny, Wasserman, & Castaneda-Sceppa, 2004). Many adults with diabetes are overweight and more than half of those with diabetes are obese (Centers for Disease & Prevention, 2004). Obesity is associated with cardiovascular risk factors including increased blood glucose (Anderson, Kendall, & Jenkins, 2003; Isomaa et al., 2001; Tirosh et al., 2011).

Obesity entails serious health concerns for more than 300 million people worldwide, representing a 50% increase in only 7 years (WHO, 2000). The tremendous challenge in efforts to lose weight or primary prevention of weight gain have become global priorities (Mozaffarian, Hao, Rimm, Willett, & Hu, 2011). Unsatisfying results regarding weight loss and attendance for treatment by life style intervention (Venditti et al., 2008) may justify an interest in the relative importance of BMI, physical activity, aerobic capacity and the risk of developing IGT and diabetes (Weinstein et al., 2004). Some overweight and physically inactive individuals might be vulnerable due to a working life that often hinders physical activity.

According to a recent review study, regular physical exercise provides a positive effect in the prevention of Type 2 diabetes (Teixeira-Lemos, Nunes, Teixeira, & Reis, 2011). Early pharmacological treatment combined with physical activity and diet may also prevent the development of Type 2 diabetes (DeFronzo & Abdul-Ghani, 2011; Lindstrom et al., 2003). Furthermore, results from a recent Norwegian intervention study suggest that more attention needs to be given to factors such as physical activity, for the individual at risk. The development of intrinsic motivation for lifestyle change appears to be one of the most important preventive factors in greater attendance (Hansen, Landstad, Hellzen, & Svebak, 2010) and, thus, may explain why results from a prospective study (Siegel et al., 2009) indicate that diabetes risk associated with a high BMI may be counteracted by vigorous exercise in men.

The present study compared aerobic capacity, physical activity level and BMI, both in men and women, as factors discriminating between healthy controls, people at risk due to IGT, and those with Type 2 diabetes. The second North-Trøndelag Health Study (1995–1997) screened the population identified by the Glucose Project (GLUP 2004). However, this study and most other previous studies on lifestyle risk factors for Type 2 diabetes have not defined the relative importance of aerobic capacity, body mass index (BMI) and self reported physical activity level as discriminating variables across the groups of individuals at different levels of risk. Thus, the aim of the present study was to investigate the relative importance and discriminant power of aerobic capacity, physical activity and body weight by BMI in people with IGT and Type 2 diabetes, and to compare these variables also including healthy controls.

MATERIAL AND METHODS

Participants

This study is based on the Second North-Trøndelag Health Survey (HUNT-2). The subjects were selected by random sampling among ~2000 persons aged 20+ in a rural community, participating with the intension to investigate the prevalence and prediction of undiagnosed hyperglycemia in the county of North-Trøndelag, Norway (Platou, Midthjell, Romundstad, Hveem, submitted for publication). In total 510 men and 605 women responded to the survey. The prevalence of screen-detected diabetes mellitus was 4.9% (4.9% men: $N=25$; 5.0% women: $N=30$), and impaired glucose tolerance 8.4% (7.5% men: $N=38$; 9.3% women: $N=56$). Among those with IGT or Type 2 diabetes ($N=149$), 32 (IGT and Type 2 diabetes) volunteered. A group of 32 healthy controls — persons free from serious illness, not under medical treatment nor on medication for blood pressure, and who had values that did not classify them as having diabetes mellitus or other categories of hyperglycaemia according to WHO (1999) guidelines — volunteered as balanced comparisons for the IGT and diabetes groups. There was no information available on socio-economic and educational status for any of the participants. However, the present sample is likely a fairly representative picture of the Norwegian population with resepect to geography, economic status, industry, source of income, age distribution, morbidity and mortality, as described and reported on for the national population at large by Holmen et al. (2003). The total sample consisted of 26 men and 38 women (IGT: $N=18$; Type 2 diabetes: $N=14$; healthy controls: $N=32$). The healthy controls were divided into two separate groups to balance for sex and age and act as reference groups for the IGT and Type 2 diabetes groups, respectively (see Table I), with the two latter groups also jointly referred to as the illness group ($N=32$). The participants were between 31 and 65 years old.

Table I. Means and standard deviations for age level and anthropometrical data of subjects in the present study (IGT: impaired glucose tolerance; Dia: Type 2 diabetes; C-IGT and C-Dia: controls to IGT and Dia, respectively).

	IGT ($N=18$)	C-IGT ($N=18$)	Diabetes ($N=14$)	C-Dia ($N=14$)
Age	45 ± 9	46 ± 10	52 ± 8	52 ± 8
Hight (cm)	169 ± 9	172 ± 7	174 ± 8	171 ± 6
Weight (kg)	81.3 ± 11.7	75.7 ± 13.6	91.5 ± 17.7	81.9 ± 15.8
BMI	28.3 ± 3.3	25.2 ± 3.7	29.9 ± 4.3	27.6 ± 4.6

Note: Total $N=64$.

Measures

Clinical measures were taken with the participants wearing undergarments without shoes; height was rounded off to the nearest 1 cm and weight to the nearest 0.5 kg, and these measures were entered into the BMI algorithm (kg/m^2). WHO categories for BMI were used to distinguish between underweight (<18.5), normal weight (18.5–24.9), overweight (25–29) and obese (≥ 30) (WHO, 2000) participants.

Diagnostic of diabetes

The glucose tolerance test identified the participants as people with Type 2 diabetes, IGT or healthy according to guidelines for an oral glucose tolerance test (WHO, 1999). The oral glucose tolerance test (OGTT) was carried out between 7.00 AM and 11.00 AM after at least 8 hours of overnight fasting. Cappilary whole blood glucose was measured by a Hemo Cue 201+® Analyzer (Hemo Cue AB, Ängelholm, Sweden). According to the producer's protocol, daily calibration and control were carried out on the Hemo Cue 201+® Analyzer. Participants whose fasting capillary whole blood glucose scored <6.1 mmol/L, rested for 2 hours and then completed the 2-hours blood glucose measurement OGTT according to WHO (1999) guidelines. The participants were informed of their glycaemic status after finishing the tests.

Criteria for inclusion

Values for diagnosis of diabetes mellitus and other categories of hyperglycaemia (WHO, 1999), based on capillary whole blood, were as follows: Impaired Glucose Tolerance (IGT): Fasting <6.1 mmol/L (110) and 2-h post glucose load ≥ 7.8 mmol/L (≥ 140) and <11.1 mmol/L (<200). Type 2 diabetes: Fasting ≥ 6.1 mmol/L (≥ 110) or 2-h post glucose load ≥ 11.1 mmol/L (≥ 200) or both.

Criteria for exclusion

Serious illness or under medical treatment, or on medication for blood pressure.

Design

The participants were enrolled in a physical fitness test, UKK walking-test for measuring aerobic capacity (Laukkanen, Oja, Ojala, Pasanen, & Vuori, 1992; UKK Institute, Finland 2002). The participants also completed questionnaires on physical activity level collected as part of the North-Trøndelag Health Survey (Kurtze, Rangul, Hustvedt, & Flanders, 2008).

Description of UKK walking-test for measuring aerobic capacity

The participants performed the 2 km UKK walking-test to indirectly measure aerobic capacity. This walking test provides an index of aerobic capacity and an estimate of maximal oxygen uptake (VO_2-max ml/kg/min). The method has been validated for adults (20–65 years) who are free from illnesses that disable walking and from heart or cardiovascular illnesses (Laukkanen, Kukkonen-Harjula, Oja, Pasanen, & Vuori, 2000; Laukkanen, Oja, Ojala, et al., 1992;

Laukkanen, Oja, Pasanen, & Vuori, 1992; Oja, Laukkanen, Pasanen, Tyry, & Vuori, 1991). The test method is designed for being carried out on flat ground outdoors. The UKK walking-test has also been validated by Bø and Hagen (2003) at the Norwegian University College for Sports. The test was evaluated as suitable for measuring aerobic capacity in large populations. The present participants responded to a questionnaire to provide information on their health before performing the UKK walking-test.

Procedures in UKK walking-test

The participants had their glucose level assessed before the UKK walking-test started. Each of the subjects wore a pulse watch to record beats per minute and time spent walking 500 m × 4, for a total distance of 2 km. The UKK aerobic capacity scores were dichotomized by median split because of low values for the present population. Low aerobic capacity was defined as scores of 28.9 ml VO_2-max ml/kg/min or below, whereas high aerobic capacity was defined as 29 ml VO_2-max ml/kg/min and above.

Description of questionnaires on self reported physical activity

Data on self-reported physical activity were collected through questionnaires with items from the large-scale population screening in the County of North-Trøndelag (HUNT-2). Physical activity was dichotomized according to response alternatives 1 or 2 in question 25 and alternative 1 in question 26 (inactive) and alternatives 3, 4 or 5 in question 25 (active) (Kurtze, et al., 2008).

Statistics

The SPSS 17.0 statistical package was applied for all statistical analyses (SPSS Inc, Chicago, Ill, USA). Bivariate coefficients of correlation were used to estimate significant inter-correlations between the variables. Potential differences in IGT/Type 2 diabetes, BMI and self reported level of physical activity associated with aerobic capacity (ml/kg/min) were investigated by analysis of variance (ANOVA). Finally, logistic regression (block-wise) was applied to investigate the relative power of discriminating between subject groups by aerobic capacity, BMI and physical activity, respectively. Dummy codes distinguished subject groups, with codes 1 and 2 given to the two healthy control groups, code 3 given to IGT and code 4 to Type 2 diabetes.

RESULTS

Table II shows that coefficients of correlation for BMI with aerobic capacity

Table II. Pearson product-moment correlations between BMI, physical activity level, aerobic capacity (VO_2-max: ml/kg/min) and the grouping code (normal, IGT or Type 2 diabetes; see Method).

Variable	BMI	Physical activity	Aerobic capacity
BMI	–		
Physical activity	−0.06	–	
Aerobic capacity	−0.76*	0.14	–
Grouping code	0.40*	0.03	−0.39*

*$p < 0.01$ level (2-tailed, $N = 64$).

($r = -0.76$, $p = 0.0004$) and the grouping variable ($r = 0.40$, $p = 0.001$) were highly significant. Furthermore, there was a significant correlation between aerobic capacity and the grouping variable ($r = -0.39$, $p = 0.001$), whereas the correlation between aerobic capacity and level of physical activity was non-significant.

Co-linearity among independent variables may cause instable models in logistic and multiple regressions. The strongest co-linearity in Table II was calculated for BMI scores with scores on aerobic capacity (around 57% of common variance). However, both variables correlated around 0.40 with the grouping variable (approximately 16% common variance), thus indicating that the IGT and Type 2 diabetes groups scored higher on BMI, but lower on aerobic capacity, than the reference group of healthy controls did. Aerobic capacity and BMI, therefore, were entered into different steps in logistic regressions to define the amount of unique variance in discriminating between the subject groups.

The ANOVA given in Table III revealed that BMI and self-reported physical activity were significantly associated with aerobic capacity ($F = 12.36$, $p < 0.001$, and $F = 4.64$, $p = 0.036$, respectively).

Table IV shows the results of blockwise logistic regression in a dichotomized approach where the IGT and Type 2 diabetes groups were referred to jointly as the "illness group" ($N = 32$). Results indicated that BMI by overweight and obesity had a significant impact on the grouping factor predicting illness (block 2: OR = 4.25, $p = 0.044$; block 3: OR = 4.09, $p = 0.052$).

Table III. ANOVA tests on associations between aerobic capacity (VO_2-max: ml/kg/min) and grouping code according to health status (healthy controls: Normal; IGT; Type 2 diabetes), BMI (normal, overweight, obese) as well as self reported level of physical activity (inactive, active).

			CI 95%			
Variable	Subgroups	Mean	Low	High	*F*-score	*p*-value
IGT/diabetes					1.22	0.30
	Normal	26.61	24.16	29.04		
	IGT	25.33	21.28	29.38		
	Diabetes	21.66	17.33	25.99		
BMI					12.36	<0.001
	Normal	33.21	29.55	36.87		
	Overweight	25.32	24.98	31.60		
	Obese	18.30	15.09	21.50		
Physical activity level					4.64	0.036
	Inactive	22.70	18.80	26.80		
	Active	26.68	24.49	28.87		

Note: Cut offs for IGT and Type 2 diabetes are presented according to guidelines by WHO (1999). BMI: Normal weight = 18.5–24, overweight = 25–29, and obese ≥ 30 (WHO, 2000). Physical activity level: see Method.
($N = 64$).

Table IV. Aerobic capacity, BMI (normal versus overweight+obese) and physical activity level as predictors for IGT/Type 2 diabetes versus controls (logistic regression, block-wise).

					CI 95%	
Variable	B	Wald	*p*-value	OR	Low	High
Block 1						
Aerobic capacity	−0.76	2.23	0.14	0.47	0.17	1.27
Block 2						
Aerobic capacity	0.14	0.04	0.84	1.16	0.29	4.53
BMI	1.45	4.07	0.04	4.25	1.04	17.29
Block 3						
Aerobic capacity	0.07	0.01	0.93	1.06	0.26	4.43
BMI	1.41	3.77	0.05	4.09	0.99	16.92
Physical activity	0.30	0.17	0.68	1.35	0.33	5.61

Note: Cut offs for IGT, Type 2 diabetes, BMI and physical activity level as in Table III. ($N = 64$).

Furthermore, the illness group was split into the two basic groups of IGT and Type 2 diabetes to test in more detail the impact of predictors in logistic regression. The results given in Table V indicated no significant relation between the independent predictors and group status for Type 2 diabetes (versus their healthy controls).

In contrast, Table VI displays significant discriminant associations between BMI scores and group status by IGT

Table V. Aerobic capacity, BMI (normal versus overweight+obese), and physical activity level as predictors of group status (diabetes versus controls; logistic regression, block-wise).

					CI 95%	
Variable	B	Wald	*p*-value	OR	Low	High
Block1						
Aerobic capacity	−0.29	0.14	0.71	0.71	0.17	3.33
Block 2						
Aerobic capacity	−0.13	0.01	0.91	0.88	0.10	7.95
BMI	0.22	0.03	0.85	1.25	0.12	13.24
Block 3						
Aerobic capacity	−0.30	0.07	0.80	0.74	0.08	7.24
BMI	0.16	0.02	0.90	1.17	0.11	12.55
Physical activity	0.62	0.35	0.56	1.85	0.24	14.45

Note: Cut offs for IGT, Type 2 diabetes, BMI and physical activity level as in Table III. ($N = 64$).

Table VI. Aerobic capacity, BMI (normal versus overweight + obese), and physical activity level as predictors of group membership (IGT versus controls; logistic regression, block-wise).

					CI 95%	
Variable	B	Wald	*p*-value	OR	Low	High
Block 1						
Aerobic capacity	−1.18	2.77	0.10	0.31	0.08	1.23
Block 2						
Aerobic capacity	0.05	0.01	0.96	1.05	0.16	6.77
BMI	2.23	5.56	0.02	9.34	1.46	59.75
Block 3						
Aerobic capacity	0.07	0.01	0.94	1.08	0.15	7.53
BMI	2.25	5.44	0.02	9.52	1.43	63.22
Physical activity	−0.11	0.01	0.92	0.893	0.11	7.49

Note: Cut offs for IGT, Type 2 diabetes, BMI and physical activity level as in Table III. ($N = 64$).

(block 2: OR = 9.34, $p = 0.018$; block 3: OR = 9.52, $p = 0.020$).

DISCUSSION

Findings in the present study indicate that BMI is the most important variable among people at risk of developing Type 2 diabetes. These findings are supported by results from earlier studies (Anderson et al., 2003; Odegaard et al., 2009; Siegel et al., 2009), which suggest that the relative importance of BMI is weakly indicated in relation to other established risk factors. BMI was significantly associated with aerobic capacity as shown in Table III ($p = 0.001$). Block II in Table IV displayed significant values for BMI overweight/obesity ($p = 0.044$, OR ≥ 4.245) in jointly predicting IGT as well as Type 2 diabetes.

Moreover, the lack of significant correlations between self-reported physical activity and aerobic capacity, as well as the grouping variable, may reflect a tendency to misrepresent actual level of physical activity when scoring subjective activity level as a lifestyle indicator. These responses were, however, validated by Kurtze, Gundersen, and Holmen (2003a,b) and Kurtze et al. (2008). Also, cut-offs may have been set somewhat arbitrarily. Therefore, an exploratory comparison was adopted in the present study where the dichotomized approach was contrasted with the continuous variable. Results stated that there only was a trivial difference between the two approaches to levels of self-reported physical activity.

BMI was measured according to WHO (1999) guidelines that are commonly used in epidemic studies even though they do not completely control for age and gender. Aerobic capacity was objectively estimated using guidelines for the 2 km UKK walking-test (UKK Institute, Finland 2002). This test is an indirect measure of aerobic capacity. The UKK walking test has been validated, however, by treadmill testing and has been proven to be an appropriate measure of VO_2-max in large populations, including adults (20–65 years) free from illnesses that prevent walking, and who are free from heart or cardiovascular diseases (Laukkanen et al., 2000; Laukkanen, Oja, Ojala, et al., 1992; Laukkanen, Oja, Pasanen, et al., 1992; Oja et al., 1991). In the present study the UKK aerobic capacity scores were dichotomized by median split because of generally low values for the present population. Consequently, a normative cut-off was not conceivable. "Low" versus "high" aerobic capacity was thus used as relative terms in the present study.

Results given in Table V, however, did not indicate a stronger correlation between BMI and Type 2 diabetes than between BMI and their healthy controls. One could argue that respondents with the diagnosis of Type 2 diabetes may already have realized the danger caused by diabetes and the risk of developing life-threatening diseases and, consequently, had taken steps in shifting towards a healthier lifestyle to reduce overweight and obesity. However, these interpretations do not correspond with results published by Venditti et al. (2008), which showed that maintenance of weight loss after intervention in individuals with diabetes seemed to be less than ideal due to low compliance with follow-up among the participants. Obviously, the combination of individuals with IGT and Type 2 diabetes as the illness group obscured different associations for BMI with status for IGT and Type 2 diabetes.

Interestingly, the results presented in Table VI support the existence of a significant association between increasing scores on BMI and a higher risk of IGT. These results suggest that attention needs to be focused in primary prevention upon efforts directed at lifestyle changes to help people with IGT to prevent the escalation into Type 2 diabetes and, in primary prevention, to help individuals avoid the risk of progressing into IGT. Thus, primary prevention of overweight and obesity may be more effective in preventing a transition to Type 2 diabetes if it is focused on individuals with IGT, or the risk of developing IGT, rather than upon weight reduction after verification of the Type 2 diabetes diagnosis.

In the prevention of lifestyle diseases like diabetes mellitus, there is little one can do to reduce factors such as heredity. Focus should be upon making changes toward a healthier lifestyle, including physical activity and eating healthy food. Also, a BMI above normal in adolescence seems to increase the risk of Type 2 diabetes later in life (Tirosh et al., 2011). This finding, therefore, suggests the need for the earliest possible primary prevention, including the avoidance of overweight already in adolescence when IGT may not yet be present. Increase in weight and signs of insulin resistance are major warnings of pathogenic mechanisms underlying the development of the metabolic syndrome (de Oliveira & Lisboa, 2011). This view was supported in a study of metabolic and vascular abnormalities in subjects at risk of developing Type 2 diabetes (Caballero, 2005). Changes in diet and increased physical activity to induce weight loss need to be implemented in the primary health care system to improve primary prevention (Lindstrom et al., 2003). Results from the present study encourage a more careful identification of people with IGT and risk of becoming overweight in primary prevention. Inactivity and moderate to low aerobic capacity, relatively speaking, appeared to be less important than BMI. Thus, primary intervention for Type 2 diabetes should target lifestyle changes that affect BMI, to prevent people from developing IGT because high BMI may present the greatest risk for developing IGT. This focus may contribute more to bringing about health gains for the general population than to reducing BMI among those diagnosed with Type 2 diabetes. This possibility should be verified in future research, and potential mechanisms should be investigated.

Multidisciplinary efforts appear to be most efficient when physicians, coaches, teachers, health pedagogues and others working in health care meet the needs of individuals. This approach appears also to be efficient in secondary prevention in primary healthcare (Sorensen, Skovgaard, & Puggaard, 2006). Positive effects have been reported from extensive interventions (Sherwin et al., 2003) although there is a need for more knowledge about the importance of dose-response relations and individualized intervention (Jallinoja, Pajari, & Absetz, 2008), and one study reported negative changes in follow-up after intervention (Venditti et al., 2008). In those with insulin dependent diabetes mellitus the prevalence of cardiovascular disease increased with age and duration of diabetes (Koivisto et al., 1996). The importance of BMI and IGT may often be confounded by such variables as age and duration of a disease and, consequently, their unique and independent importance in prevention may be underestimated. Challenges faced by such marginalized groups can include reduced capacity and therewith a risk of becoming vulnerable to exclusion from working life, due to the risk of developing illness in the future. The present results suggest that, for the IGT group, prevention of overweight and obesity should be highly important targets in primary as well as secondary prevention. However, in focusing upon maintaining a healthy BMI the fact that moderate to high levels of physical activity, increased aerobic capacity, as well as healthy dieting often have indirect beneficial effects upon BMI should not be forgotten. Obviously, the present results support the assumption that the latter factor is of particularly high importance in primary prevention of IGT and that the latter factors indirectly support achieving this goal.

Potential limitations to the study are the cross-sectional approach and the limited samples of subjects with IGT and Type 2 diabetes (IGT: $N=18$/ healthy controls: $N=18$, Type 2 diabetes: $N=14$/ healthy controls: $N=14$). Larger populations may have increased the external validity of findings, and these effects upon the relative importance of level of physical activity, aerobic capacity and BMI can only be tested in an experimental approach with larger samples.

CONCLUSIONS

The present results indicate that a healthy BMI is of primary importance in the prevention of IGT and, therefore, also in the primary prevention of Type 2 diabetes.

CONFLICT OF INTEREST AND FUNDING

There is no conflict of interest among the authors.

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REFERENCES

Alberti, K.G., Zimmet, P., & Shaw, J. (2007). International Diabetes Federation: A consensus on Type 2 diabetes prevention. *Diabet Med*, 24(5), 451–463. doi: DME 2157 [pii] 10.1111/j.1464-5491.2007.02157.x

Anderson, J.W., Kendall, C.W., & Jenkins, D.J. (2003). Importance of weight management in type 2 diabetes: Review with meta-analysis of clinical studies. *Journal of the American College of Nutrition*, *22*(5), 331–339.

Association, W.M. (2008). *Declaration of Helsinki: Ethical principles for medical research involving human subjects*. Retrieved 29 April 2010, from http://www.wma.net/en/30publications/10policies/b3/17c.pdf

Boursier, V. (2006). Le syndrome metabolique. [Metabolic syndrome]. *Journal des Maladies Vasculaires*, *31*(4 Pt 1), 190–201.

Bø, K., & Hagen, L.A. (2003). Utprøving av UKK Testbatteri for måling av fysisk form hos voksne (20–65år). Norges Idrettshøyskole.

Caballero, A.E. (2005). Metabolic and vascular abnormalities in subjects at risk for type 2 diabetes: The early start of a dangerous situation. *Archives of Medical Research*, *36*(3), 241–249.

Cederholm, J., & Wibell, L. (1991). Impaired glucose tolerance: Influence by environmental and hereditary factors. *Diabetes and Metabolism*, *17*(2), 295–299.

Centers for Disease & Prevention. (2004). Prevalence of overweight and obesity among adults with diagnosed diabetes—United States, 1988–1994 and 1999–2002. *Morbidity & Mortality Weekly Report*, 53(45), 1066–1068.

de Oliveira, J.M., & Lisboa, L.B. (2011). Adolescent BMI and risk of diabetes versus coronary disease. *The New England Journal of Medicine*, 364(26), 2558; author reply 2559. doi: 10.1056/NEJMc1105425#SA1

DeFronzo, R.A., & Abdul-Ghani, M. (2011). Type 2 diabetes can be prevented with early pharmacological intervention. *Diabetes Care*, 34, S202–S209. doi: 10.2337/dc11-s221

GLUP (2004). Glukosebelastningsprosjektet, Fysisk form og fysisk aktivitet. Nord - Trøndelag University College and Helseundersøkelsen i Nord - Trøndelag (HUNT).

Hansen, E., Landstad, B.J., Hellzen, O., & Svebak, S. (2010). Motivation for lifestyle changes to improve health in people with impaired glucose tolerance. *Scandinavian Journal of Caring Sciences*, doi: 10.1111/j.1471-6712.2010.00853.x

Holmen, J., Midthjell, K., Kruger, Ø., Langhammer, A., Lingaas Holmen, T., Bratberg, G.H., … Lund-Larsen, P.G. (2003). The Nord - Trøndelag Health Study 1995–97 (HUNT 2): Objectives, contents, methods and participation. *Norsk Epidemiologi*, *13*(1), 19–32.

Isomaa, B., Almgren, P., Tuomi, T., Forsen, B., Lahti, K., Nissen, M., et al. (2001). Cardiovascular morbidity and mortality associated with the metabolic syndrome. *Diabetes Care*, *24*(4), 683–689.

Jallinoja, P., Pajari, P., & Absetz, P. (2008). Repertoires of lifestyle change and self-responsibility among participants in an intervention to prevent type 2 diabetes. *Scandinavian Journal of Caring Sciences*, 22(3), 455–462. doi: SCS551 [pii] 10.1111/j.1471-6712.2007.00551.x

Koivisto, V.A., Stevens, L. K., Mattock, M., Ebeling, P., Muggeo, M., Stephenson, J., et al. (1996). Cardiovascular disease and its risk factors in IDDM in Europe. EURODIAB IDDM Complications Study Group. *Diabetes Care*, *19*(7), 689–697.

Kurtze, N., Gundersen, K.T., & Holmen, J. (2003a). Selvrapportert fysisk aktivitet i norske befolkningsundersøkelser — et metodeproblem. *Norsk Epidemiology*, *13*, 163–170.

Kurtze, N., Gundersen, K.T., & Holmen, J. (2003b). Selvrapportert fysisk aktivitet i 1980-og 1990-årene — Helseundersøkelsen i Nord-Trøndelag (HUNT). *Norsk Epidemiology*, *13*, 171–176.

Kurtze, N., Rangul, V., Hustvedt, B.E., & Flanders, W.D. (2008). Reliability and validity of self-reported physical activity in the Nord-Trondelag Health Study: HUNT 1. *Scandinavian Journal of Public Health*, 36(1), 52–61. doi: 36/1/52 [pii] 10.1177/1403494807085373

Laukkanen, R., Oja, P., Pasanen, M., & Vuori, I. (1992). Validity of a two kilometre walking test for estimating maximal aerobic power in overweight adults. *International Journal of Obesity & Related Metabolic Disorders: Journal of the International Association for the Study of Obesity*, *16*(4), 263–268.

Laukkanen, R.M., Kukkonen-Harjula, T.K., Oja, P., Pasanen, M.E., & Vuori, I.M. (2000). Prediction of change in maximal aerobic power by the 2-km walk test after walking training in middle-aged adults. *International Journal of Sports Medicine*, 21(2), 113–116. doi: 10.1055/s-2000-8872

Laukkanen, R. M., Oja, P., Ojala, K. H., Pasanen, M. E., & Vuori, I. M. (1992). Feasibility of a 2-km walking test for fitness assessment in a population study. *Scandinavian Journal of Society and Medicine*, *20*(2), 119–126.

Lindstrom, J., Louheranta, A., Mannelin, M., Rastas, M., Salminen, V., Eriksson, J., et al. (2003). The Finnish Diabetes Prevention Study (DPS): Lifestyle intervention and 3-year results on diet and physical activity. *Diabetes Care*, *26*(12), 3230–3236.

Mozaffarian, D., Hao, T., Rimm, E.B., Willett, W.C., & Hu, F.B. (2011). Changes in diet and lifestyle and long-term weight gain in women and men. *The New England Journal of Medicine*, 364(25), 2392–2404. doi: 10.1056/NEJMoa1014296

Odegaard, A.O., Koh, W.P., Vazquez, G., Arakawa, K., Lee, H.P., Yu, M.C., et al. (2009). BMI and diabetes risk in Singaporean Chinese. *Diabetes Care*, 32(6), 1104–1106. doi: dc08-1674 [pii] 10.2337/dc08-1674

Oja, P., Laukkanen, R., Pasanen, M., Tyry, T., & Vuori, I. (1991). A 2-km walking test for assessing the cardiorespiratory fitness of healthy adults. *International Journal of Sports Medicine*, 12(4), 356–362. doi: 10.1055/s-2007-1024694

Rennie, K.L., Wells, J.C., McCaffrey, T.A., & Livingstone, M.B. (2006). The effect of physical activity on body fatness in children and adolescents. *Proceedings of the Nutrition Society*, *65*(4), 393–402.

Sherwin, R.S., Anderson, R.M., Buse, J.B., Chin, M.H., Eddy, D., Fradkin, J., et al. (2003). The prevention or delay of type 2 diabetes. *Diabetes Care*, *26*(Suppl 1), 62–69.

Siegel, L.C., Sesso, H.D., Bowman, T.S., Lee, I.M., Manson, J.E., & Gaziano, J.M. (2009). Physical activity, body mass index, and diabetes risk in men: A prospective study. *American Journal of Medicine*, 122(12), 1115–1121. doi: S0002-9343(09)00143-0 [pii] 10.1016/j.amjmed.2009.02.008

Sigal, R.J., Kenny, G.P., Wasserman, D.H., & Castaneda-Sceppa, C. (2004). Physical activity/exercise and type 2 diabetes. *Diabetes Care*, 27(10), 2518–2539. doi: 27/10/2518 [pii]

Sorensen, J.B., Skovgaard, T., & Puggaard, L. (2006). Exercise on prescription in general practice: A systematic review. *Scandinavian Journal of Primary Health Care*, 24(2), 69–74. doi: Q686NV72083402M1 [pii] 10.1080/02813430600700027

Teixeira-Lemos, E., Nunes, S., Teixeira, F., & Reis, F. (2011). Regular physical exercise training assists in preventing type 2 diabetes development: Focus on its antioxidant and anti-inflammatory properties. *Cardiovascular Diabetology*, *10*, 12.

Tirosh, A., Shai, I., Afek, A., Dubnov-Raz, G., Ayalon, N., Gordon, B., et al. (2011). Adolescent BMI trajectory and risk of diabetes versus coronary disease. *The New England Journal of Medicine*, 364(14), 1315–1325. doi: 10.1056/NEJMoa1006992

Venditti, E.M., Bray, G.A., Carrion-Petersen, M.L., Delahanty, L.M., Edelstein, S.L., Hamman, R.F., et al. (2008). First versus repeat treatment with a lifestyle intervention program: Attendance and weight loss outcomes. *International Journal of Obesity (London)*, 32(10), 1537–1544. doi: ijo 2008134 [pii] 10.1038/ijo.2008.134

Weinstein, A.R., Sesso, H.D., Lee, I.M., Cook, N.R., Manson, J.E., Buring, J.E., et al. (2004). Relationship of physical activity vs body mass index with type 2 diabetes in women. *The Journal of the American Medical Association*, 292(10), 1188–1194. doi: 10.1001/jama.292.10.1188 292/10/1188 [pii]

WHO. (1999). *Definition, diagnosis and classification of diabetes mellitus and its complications: Report of a WHO consultation. Part 1, Diagnosis and classification of diabetes mellitus* (pp. 59). Geneva: World Health Organization, Department of Noncommunicable Disease Surveillance.

WHO. (2000). *Obesity: Preventing and managing the global epidemic; report of aWHO consultation*. (WHO technical report series, Vol. 894, pp. xii, 253). Geneva: WHO.

Wild, S., Roglic, G., Green, A., Sicree, R., & King, H. (2004). Global prevalence of diabetes: Estimates for the year 2000 and projections for 2030. *Diabetes Care*, *27*(5), 1047–1053.

Williams, G.C., Freedman, Z.R., & Deci, E.L. (1998). Supporting autonomy to motivate patients with diabetes for glucose control. *Diabetes Care*, *21*(10), 1644–1651.