Nutrición Hospitalaria

Nutr Hosp. 2015;32(4):1729-1734
ISSN 0212-1611 • CODEN NUHOEQ
S.V.R. 318

Original/*Deporte y ejercicio*

Effects of training and detraining on glycosylated haemoglobin, glycaemia and lipid profile in type-II diabetics

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Abstract

Objective: **the aim of the present study was to determine the effect of training and the consequences of detraining, comparing an aerobic training (AT) protocol with a resistance training (RT) in people with type-II Diabetes Mellitus (DMII).**

Methods: **a total of 30 individuals participated in the study, with ages ranging from 45 to 50 years, all diagnosed with DMII and not currently receiving pharmacological treatment. Participants were divided at random into an AT group (65% of their maximum aerobic capacity) and a RT group (1 x 2 x 3 protocol at 65% of 1RM). Measurements were taken of weight, body mass index, total cholesterol, HDL-C, LDL-C, triglycerides, glycaemia in a fasted state and glycosylated haemoglobin (HbA_{1C}) at the beginning and at the end of the 6-week training period, and after a further 6 weeks of detraining.**

Results: **the results show that both physical training protocols are capable of inducing significant modifications in lipid profile, glycaemia in a fasted state and levels of HbA_{1C}; however, after stopping the training programme only the RT group maintained the benefits of the reduction in LDL-C, HbA_{1C} and the increase in HDL-C.**

Conclusions: **resistance exercise in individuals with DMII has an important influence on health and their effects could be maintained even if the training program is interrupted short-term.**

(*Nutr Hosp*. 2015;32:1729-1734)

DOI:10.3305/nh.2015.32.4.9341

Key words: *Type-II diabetes mellitus. Aerobic exercise. Resistance exercise. Detraining. Health.*

EFECTOS DEL ENTRENAMIENTO Y EL DESENTRENAMIENTO FÍSICO SOBRE LA HEMOGLOBINA GLUCOSILADA, LA GLUCEMIA Y EL PERFIL LIPÍDICO EN DIABÉTICOS TIPO II

Resumen

Objetivo: **el propósito del presente estudio fue determinar el efecto del entrenamiento y las consecuencias del desentrenamiento comparando un protocolo de entrenamiento aeróbico (E-Aer) y otro de sobrecarga (E-Sob).**

Métodos: **participaron 30 personas entre 45-50 años de edad con diagnóstico de diabetes mellitus tipo II (DMII) sin tratamiento farmacológico. Fueron aleatorizados a un grupo de E-Aer (65% de su esfuerzo máximo) o a un grupo de E-Sob (protocolo 1 x 2 x 3 al 65% de 1RM). Se midió el peso, el índice de masa corporal, el colesterol total, HDL-C, LDL-C, triglicéridos, glucemia en ayuno y la hemoglobina glucosilada (HbA_{1C}) al inicio, al finalizar las seis semanas de entrenamiento y tras seis semanas de desentrenamiento.**

Resultados: **los resultados indican que ambos protocolos de entrenamiento físico son capaces de inducir modificaciones significativas en el perfil lipídico, la glicemia en ayuno y los niveles de HbA_{1C}; sin embargo, solo el grupo E-Sob demostró mantener los beneficios logrados tras haber interrumpido el programa de entrenamiento en la reducción del LDL-C, HbA_{1C} y en el incremento del HDL-C.**

Conclusiones: **el ejercicio de sobrecarga en personas con DMII influye de manera importante en la salud, efecto que podría mantenerse incluso si se llega a interrumpir a corto plazo el programa de entrenamiento.**

(*Nutr Hosp*. 2015;32:1729-1734)

DOI:10.3305/nh.2015.32.4.9341

Palabras clave: *Diabetes mellitus tipo II. Ejercicio aeróbico. Ejercicio de sobrecarga. Desentrenamiento. Salud.*

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Recibido: 2-VI-2015.
Aceptado: 26-VII-2015.

Abbreviations

AT: Aerobic Training.
RT: Resistance Training.
DMII: Diabetes Mellitus type-II.
HDL-C: High Density Lipoprotein Cholesterol.
LDL-C: Low Density Lipoprotein Cholesterol.
HbA_{1C}: Glycosylated Haemoglobin A_{1C}.
BMI: Body Mass Index.
GLUT-4: Glucose transporters 4.
YMCA: Young Men's Christian Association.
VLDL: Very Low Density Lipoprotein.
1RM: 1-Repetition Maximum.
ANOVA: Analysis of variance.

Introduction

Doing regular physical exercise has been proven to have a positive effect on the pathogenicity of several diseases[1,2]. However, little is known about the effect of detraining on difference health markers in persons with DMII. Both aerobic exercise[3,4] and resistance exercise[4-6] or a combination of these in the same training session[7,8] have been shown to be an important non-pharmacological therapeutic complement to controlling DMII. It has been documented that exercise positively influences HbA_{1C}, body mass index (BMI), oxygen consumption, glucose in a fasted state and postpandrial glucose, and others[4,7]. Nevertheless, at present there is insufficient information on how these parameters are altered by an interruption in training due to illness, holidays, injury, travel, etc[7].

Partially or fully suspending training causes different alterations on a physiological level in the short and long term[9,10]. Some consequences of detraining, such as decreased bradycardia at rest[11], decreased vagal reactivation[12], deregulation of insulin secretion and glucose concentration[13], decreases in GLUT-4 transporter[14], modified lipid profile[15], among others, may considerably worsen the health of persons with DMII.

To date, studies involving animals[14,16] and humans[4] have provided valuable information on the consequences of detraining. However, in the literature, no research has determined the effect of training and the consequences of detraining, comparing an AT and an RT protocol. Therefore, the principal objective of the present study is to determine the differences between these two training protocols on body weight, BMI, HbA_{1C}, glucose concentration after fasting and lipid profile in a group of non-medicated individuals with DMII.

Materials and Methods

Participants

A total of 30 adults from the Young Men's Christian Association (YMCA) health programme participated in the study (21 women and 9 men, aged 48.1 ± 1.7 years, with heights of 1.66 ± 0.0 m, weight of 71.7 ± 6.1 kg, BMI of 26.0 ± 2.1 kg/m^2). The inclusion criteria were men and women aged 45 to 50 years, diagnosed with DMII for at least 2 years and not currently using pharmacological treatment. Any person not completing the training programme, or those who completed less than 70% of the sessions were excluded (8 subjects, 21%). The study was carried out in accordance with international deontological standards for research involving human beings, as established in the Helsinki Declaration, and it was approved by the local ethics committee. All participants voluntarily signed an informed consent form and were fully aware of the procedures and objectives of the study.

Blood analysis

All participants visited the clinical laboratory on three occasions to determine their fasted glucose levels (after 12 h of fasting), lipid profile (total cholesterol, HDL-C, LDL-C and triglycerides (mg/dL) and HbA_{1C} (%), at the start of the study, at the end of the first training period and after the detraining period. The procedure was carried out by extracting 10 ml of blood in a vacutainer with EDTA between 7:30 am and 9:00 am. After centrifugation, the blood serum was separated within one hour of taking the sample. It should be noted that the laboratory personnel were blind to the study.

Glucose concentration was determined using the Reflolux S-1172115 glucometer (Boehringer Mannheim, Germany) based on the glucose-oxidase method.[17] Total cholesterol, HDL-C, LDL-C and triglycerides were measured by enzyme methods[18]. High density lipoproteins were measured by VLDL and LDL-C precipitation in the presence of magnesium ions. The LDL-C fraction was calculated using the Friedewald formula. HbA_{1C} (%) was measured by the immunoturbidimetric test using an automatic Cobra Integra 800 analyser (Roche Diagnostics, Switzerland) with a reference value of 4.4 to 6.4%. This methodology was in line with the standards of the National Glycated Haemoglobin Standardisation Programme[19].

Physical training

The participants were randomly divided into two groups (aerobic and resistance). Each person on the AT group performed the modified Bruce protocol to estimate oxygen consumption indirectly and identify 65% of maximum aerobic capacity (the training level for the aerobic group). For the RT group, their 65% maximum strength was estimated using the 1-repetition maximum protocol (1RM). This protocol begins with a warm-up with a weight that is sufficiently light to allow at least 15 repetitions. The weight is then gradually increased until the subject can only perform one repetition, equivalent to 100% of their maximum strength. The test had a maximum of 6 series per muscle group, allowing a rest time of 3 minutes between each series in order to avoid excessive fatigue in the necessary zone.

The participants attended 3 sessions per week at the YMCA gym for a period of 6 weeks. The AT group warmed up for 10 minutes by walking, followed by 30 minutes continuous running and 10 minutes of warm-down. The RT group performed the 1x2x3 protocol (as many repetitions as possible during 1 minute, with 2 minutes rest, for 3 series)[20]. Eight separate muscle groups were worked: elbow flexors and extensors, wrist flexors and extensors, knee flexors and extensors, and ankle flexors and extensors. The length of the training periods for both groups was set at 50 minutes.

During the 12 weeks of the study, the participants were asked to maintain their normal habits regarding eating and physical activity. During the 6 weeks of training, no other type of exercise was carried out other than the session indicated in the study. For the period of 6 weeks of detraining, they were not allowed to perform any type of physical activity or training that could lead to bias in the results.

Statistical analysis

In order to determine the effect of the type of training and of the detraining, an ANOVA test was applied. When transferring the sphericity assumptions, the Geisser correction factor was applied. A Bonferroni test was used post hoc in all pair comparisons when a significant result was found. The variation scores of all measurements (pre-training, post-training and post-detraining) were also analysed. Finally, the size of the effect on each group was calculated (using Cohen's d). The effect size was established in accordance with the following interpretation: trivial (0-0.19), small (0.20 to 0.49), medium (0.50 to 0.79) and large (0.80 and above)[21].

Results

Both the AT and the RT protocols led to positive changes after 6 weeks. The AT protocol saw significant improvements on almost all health indices, apart from HbA_{1C} and triglycerides. The RT group also saw significant changes in almost all indices, except for weight and BMI (Table I).

During the 6 weeks without physical training it can be seen that for the AT group the indices that had improved during the training period deteriorated significantly, apart from HDL-C which remained relatively low. It is important to note the results for HbA_{1C}, which did not reduce significantly during the aerobic training but did rise significantly during the detraining period in comparison to the pre-training values. (Table I).

For the RT protocol, several indices that had improved during training also deteriorated, though LDL-C remained low and HDL-C remained high. The pronounced increase in HbA_{1C} was not seen during detraining as was observed with the AT group. (Table I).

With regard to effect size, Table II shows the values for Cohen's *d*. Both groups followed the same trend, except for weight and BMI (positive values for the RT group, but a small effect with $d < 0.2$) and glycaemia and triglycerides (negative values for the RT group, but a small effect with $d < -0.2$).

Discussion

The results of this study are in agreement with the literature with regard to the importance of physical training as a non-pharmacological therapeutic tool,

Table I
Differences between pre-training, post-training and 6 weeks of detraining

	Aerobic group			*Resistance group*		
	Pre-training	*Post-training*	*Detraining*	*Pre-training*	*Post-training*	*Detraining*
Weight (Kg)	74.1±4.1*	73.1±5.0*†	73.1±5.8*	69.3±6.3	68.8±6.7	69.7±6.3§
BMI ($Kg \cdot m^{-2}$)	27.2±2.2*	26.8±2.3*†	26.8±2.3*	24.9±1.2	24.7±1.4	25.0±1.2§
Total cholesterol ($mg \cdot dl^{-1}$)	213.0±39	202.1±33.3†	210.2±32.7	197.1±33.0	180.5±23.7†	188.9±25.6§
LDL cholesterol ($mg \cdot dl^{-1}$)	147.5±39.3	133.5±31.6*†	143.5±32.3*§	130.3±27.4	107.4±22.7†	116.9±15.0‡
HDL cholesterol ($mg \cdot dl^{-1}$)	37.6±7.7	42.7±6.8†	38.7±6.2§	40.1±8.6	45.5±6.5†	43.5±5.9§‡
Triglycerides ($mg \cdot dl^{-1}$)	133.5±55.9	129.4±49.5	137.1±50.6§	153.5±56.6	137.9±47.6†	144.3±47.8§
Glycaemia ($mg \cdot dl^{-1}$)	129.0±39.5	118.0±34.0†	130.0±33.5§	112.3±36.1	105.7±30.1†	110.3±31.2§
Glycosylated haemoglobin (%)	6.7±3.1*	6.3±0.8	7.3±0.4§‡	7.2±0.6	6.7±0.7†	7.4±0.4§

*Differences between the aerobic and resistance groups. †Difference between pre and post-training. §Differences between post-training and detraining. ‡ Differences between pre-training and detraining.

Table II
Calculations of effect size between groups (Cohen's d) from pre-training, post-training and 6 weeks of detraining

	Aerobic group			*Resistance group*		
	Pre vs. Post	*Post vs. detraining*	*Pre vs. detraining*	*Pre vs. Post*	*Post vs. detraining*	*Pre vs. detraining*
Weight (Kg)	-0.21	0.01	-0.20	-0.08	0.14	0.07
BMI ($Kg \cdot m^{-2}$)	-0.17	0.00	-0.17	-0.16	0.25	0.13
Total cholesterol ($mg \cdot dl^{-1}$)	-0.28	0.24	-0.07	-0.50	0.35	-0.25
LDL cholesterol ($mg \cdot dl^{-1}$)	-0.36	0.32	-0.10	-0.84	0.42	-0.49
HDL cholesterol ($mg \cdot dl^{-1}$)	0.66	-0.59	0.14	0.62	-0.32	0.39
Triglycerides ($mg \cdot dl^{-1}$)	-0.07	0.16	0.06	-0.28	0.14	-0.16
Glycaemia ($mg \cdot dl^{-1}$)	-0.28	0.37	0.03	-0.18	0.15	-0.06
Glycosylated haemoglobin (%)	-0.79	1.24	1.47	-0.72	0.90	0.26

showing significant improvements to body composition, lipid profile, glycaemia and HbA_{1C}, which undoubtedly represent improved general health for persons with DMII. It is also important to note that this study analyses the effects of physical exercise on different health indicators without making any modifications to the eating habits of a group of people who do not take any type of medication linked to their clinical diagnosis, an aspect that is very uncommon in this line of research. Lastly, this study provides valuable information by comparing the effect size of detraining on health after application of two commonly used training protocols in this population group: aerobic and resistance.

It is well established that there are differences generated in body composition and especially weight when using an aerobic training protocol and a resistance training protocol.[22] It has been shown that aerobic training significantly decreases weight and body fat, while resistance training does not always lead to notable weight loss, even leading to an increase in weight, which has been linked to an increase in muscle mass[22]. In the present study, a pronounced and significant decrease in weight is seen in the AT group. This is similar to the results obtained when combining the two types of training (aerobic and resistance) in the same session[7]. The interesting aspect is that the body weight lost via aerobic training is maintained up to 6 weeks after the last training session. This effect is not seen with the RT group, in which case the body weight figures rise above reference values.

With regard to the benefits of the protocols in question on glycaemia in a fasted state, it can be stated that the changes observed after the training period are lower than those reported in other studies[23-25]. However, it should be noted that the duration of the training period[26], the number of years since DMII diagnosis[27] and the manipulation of the participants' food intake[24,28] appear to significantly influence the results in this type of study.

It is also important to note that though glycaemia in a fasted state is significantly reduced with both protocols after 6 weeks of training, only the RT group was able to maintain the effect after stopping the exercise programme. A similar effect has been reported when combining aerobic and resistance exercise in the same training session.[7] However, in the present study in the aerobic group not only did the values increase but they also went further than the values prior to training, which somewhat underlines the benefits to glycaemia of the 1x2x3 resistance training protocol used in the study.

The two study protocols were also seen to be effective at improving the lipid profile of the participants after training. The only marker that did not see significant improvement was triglycerides with the aerobic protocol. However, in general the results are in agreement with the literature on the benefits of regular physical exercise with regard to concentration levels of LDL-C, HDL-C, triglycerides and total cholesterol[29,30].

An interesting finding can be seen during the detraining period of the RT group. This type of training showed an important effect on maintaining high levels of HDL-C and maintaining reduced levels of LDL-C, despite fully stopping physical exercise. However, in another study that included a combination of aerobic and resistance exercise in the same session, the improvements in HDL-C and LDL-C levels were not maintained after 8 weeks of detraining[4]. The differences in the training programmes (time, intensity, energy expenditure, etc.) make it very difficult to compare and analyse the differences between the results of the studies.

With regard to the levels of HbA_{1C}, this index decreased with both protocols, as is well documented in the literature as an effect of a programme of physical exercise[26]. However, only the RT group saw significant reductions. Another interesting aspect is that the values after the detraining period increased to levels above the reference values for both groups, though the increase was only significant for the AT group, in a similar result to what was seen for glycaemia.

The results obtained in the present study show that resistance training fulfils an important function within a training plan. It has been documented that the combination of aerobic and resistance training generates an effect that may further enhance the effect on health in comparison to applying each training protocol separately[4,26,27,29]. However, it should be noted that resistance training has different methodologies that can influence the results, such as the working intensity, number of repetitions, number of series, etc. For example, the good results obtained in the study by Sigal et al.[26] and by Park and Lee[8] use programmes with 7-9 and 10-12 repetitions, respectively, using a range of intensities from 45 to 75% of 1-repetition maximum (1RM)[8]. Nevertheless, there are also other types of protocols, such as the "as many repetitions as possible" used in the present study, and which have not been subject to the same level of research.

The results of the present study, which underline the effect of resistance training, may be due to the intracellular effect generated by localised muscle fatigue. It has been documented that the alteration of different cytosolic messengers (Ca2+, Adenosín monofosfato, Inorganic phosphate, creatine, hydrogen ion, lipid intermediates) is an important trigger to the stimulation of AMP-activated protein kinase[31] and peroxisome proliferator-activated receptor-gamma coactivator 1-alpha,[32,33] proteins that promote a series of physiological changes (increased GLUT-4, capillarisation, increased fatty acid transported proteins, etc.)[32,34,35]. Though these changes can be generated with a traditional training protocol, such as 10-12 repetitions at ~70% of 1RM[4,27,30], it seems that a protocol that leads to increased localised fatigue, such as the 1x2x3 protocol, may induce a greater effect in a shorter timeframe. This would validate the results obtained for glycaemia levels[31].

In addition to the factors described above, the variations seen in HDL-C and LDL-C may also be linked to the duration of the programme and mainly to weight loss, as documented in previous studies[26,36,37]. In the case of HbA_{1C}, there is no complete clarity as to how aerobic, resistance or a combined exercise protocol effects this index[27]. However, the results obtained in the present study (decreases of 0.4 and 0.5% with aerobic and resistance training, respectively) are very similar to those obtained in other studies[8,27]. This decrease can be seen as extremely important when considering that a reduction of 1% in HbA_{1C} can decrease the risk of a cardiovascular event by 15 to 20%[38].

In another context, it can be stated that there were certain limitations to the present study, such as a lack of a control group without exercise[39], no rigorous monitoring of participants' calorie intake and diet quality[28], lack of a deeper analysis of body composition, etc. These factors must be considered in any future studies.

Finally, we can conclude that both the aerobic and the resistance training protocols are able to improve lipid profile, glycaemia in a fasted state and the level of HbA_{1C} in persons with DMII. However, after 6 weeks of detraining, the RT protocol was shown to be more effective at maintaining the effects attained on HDL-C, LDL-C and HbA_{1C}.

Conflict of Interest

None declared

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