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Impact of physical activity in glycaemic control of Type 2 diabetic adults amongst the Maltese population

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Abstract
Type 2 diabetes has become a great source of concern to governments, individuals and health care givers all over the world because of its serious long-term complications, such as blindness, kidney disease, heart disease, stroke, limb amputation and reduced life expectancy. Therefore, this study sets out to investigate the impact of physical activity in glycaemic control of Type 2 diabetic adults amongst the Maltese population. Well structured questionnaires were administered on a hundred and twenty patients who were regularly attending the Diabetes Clinic, at St. Luke's Hospital, aged 30 to 44 years. They were informed that the questionnaires were designed for people with Type 2 diabetes. Only hundred patients responded and attended the first meeting prior to the exercise programme. These patients were randomly assigned into control and intervention groups using random sampling technique. Data collected from respondents were analyzed, put into Tables and were subjected to descriptive statistics and analysis of variance (ANOVA). Results obtained showed that there were significant differences in HbA1c ($p<0.005$) and weight ($p=0.001$). The Intervention group HbA1c values and weight were significantly reduced ($p<0.005$) when compared with the control group, suggesting that exercise has an impact on the glycaemic control of Type 2 diabetes mellitus. This further reinforces the importance of exercise of any intensity on these two parameters. The difference in cholesterol was not significant but improved remarkably ($p=0.008$) which indicated that the difference is not big in magnitude. The improvement on glycaemic control correlated strongly with consistence in exercise programme $(r = 0.333)^2$. The recommendation that exercise training can be used as a therapeutic means to lower blood glucose levels in Type 2 diabetes mellitus stems primarily from the fact that exercise has pronounced effects upon the metabolism of glucose. Further studies are recommended to elucidate how the metabolic effect of physical activity and Type 2 diabetes are modulated by duration of diabetes and

intensity of exercise on the glycaemic control and lipid profile.

1. Introduction

Type 2 diabetes is a chronic condition affecting both young and old. Prevalence of Type 2 diabetes has tripled in the last 30 years, and estimates show that there are about 180 million people with diabetes in the world (Health Canada, 2002). The World Health Organisation estimates that by the year 2025 there will be 300 million people with the disease worldwide (WHO, 2000).

Type 2 diabetes is steadily increasing in Malta (Department of Health Information, 2001). The Government has recognized it as a public health problem and has been doing her best to alleviate the problems of diabetes mellitus since early 1980. However, more needs to be done to reduce the onset of this disease and minimize the complications. Statistics from the World Health Organisation (2000) suggests that about 30,000 people have diabetes in Malta, and estimates that about 50,000 people will have diabetes by the year 2025. The impact of diabetes is not only felt in Malta. It has estimated that four out of ten persons with diabetes will develop serious long-term complications, such as blindness, kidney disease, heart disease, stroke, limb amputation and reduced life expectancy (American Diabetes Association, 2001). Therefore, it can be inferred that Maltese adults with diabetes are twice as likely to die prematurely, compared to persons without diabetes. In addition, Health Canada (2002) argues that life expectancy for people with Type 2 diabetes may be shortened by 5 to 10 years.

The financial burden on the Maltese health care system of diabetes and its complications is enormous. Diabetes is a costly disease and so are the hidden costs such as loss of productivity from sickness, disability and premature death. The complications can limit life, quality of life, and do inflict an incredible burden on national healthcare system. It is estimated that a person with diabetes incurs medical costs that are two or three times higher than that of a person without disease.

Pharmaceutical therapy aimed at tightly controlling blood glucose levels is considered a cost-effective strategy that can reduce complications, improve quality of life, and may potentially improve longevity in people with Type 2 diabetes (Ohkubo et al, 1995, UK Prospective Diabetes Study Group 1998a). Controlling blood pressure through pharmaceutical means reduces the risk of macro vascular diseases, including myocardial infarction, sudden death, stroke, and peripheral vascular disease (UK Prospective Diabetes Study Group, 1998b). On the contrary, non-pharmaceutical interventions for Type 2 diabetes that can produce similar effects on glycaemia and hypertension, or at least enhance the pharmaceutical intervention are urgently needed.

Exercise has long been considered a cornerstone in the management of Type 2 diabetes. Recently epidemiological evidence has emerged that demonstrates that low cardio-respiratory fitness and physical inactivity are independent predictors of all-cause mortality in men with Type 2 diabetes (Wei et al, 2000). Schranz et al (1997) acknowledged the important role of physical activity and exercise in the management of Type 2 diabetes at all stages of treatment. Exercise should be undertaken with the goals of improving glycaemic control, increasing insulin sensitivity, and reducing the risk of cardiovascular disease (Meltzer et al 1998). It has a pronounced effect on substrate utilisation, and muscle glucose uptake can increase by up to 20- fold during exercise (Eriksson, 1999). Several studies have evaluated the effect of exercise on insulin sensitivity and glycaemic control in patients with Type 2 diabetes mellitus. The results obtained have been highly heterogenous regarding the effect of exercise on insulin sensitivity and glycaemic control. Eriksson (1999) suggests that only in certain subgroups of patients with Type 2 diabetes mellitus especially those less than 55 years of age, treated through diet and have fairly good metabolic control, does exercise seem to be beneficial with regard to improvement in glycaemic control.

In the early stages of Type 2 diabetes, blood glucose levels can often be controlled with changes in diet and physical activity along with sulfonylureas. Unfortunately, β-cell dysfunction that leads to impaired insulin secretion is progressive, and eventually patients will require a treatment strategy that includes insulin, either alone or with oral agents and exercise (Wright et al, 2002). Although, there is no cure for diabetes, two large controlled studies, the Diabetes Control and Complications Trial DCCT (1993) and the UK Prospective Diabetes Study (UKPDS) cited by Stratton et al (2000) have pointed to the importance of intensive blood glucose control in reducing its associated morbidity. The Japanese Kumanoto study also found that intensive glycaemic control reduced the risk for retinopathy, nephropathy, and neuropathy in patients with Type 2 diabetes (Ohkubo et al, 1995).

Moderate intensity exercise stimulates the secretion of glucagon, which acts in tandem with decreasing insulin levels to increase hepatic glucose output and blood glucose levels during moderate exercise is impaired with Type 2 diabetes compared with non-diabetics (Jenkins et al, 1988). In Malta, most individuals with diabetes aged 30-44 are overweight (Shranz et al, 1997). Modest weight loss about 10% in individuals with Type 2 diabetes can improve glycaemic control, insulin sensitivity and lipid profiles (Bosello et al, 1997).

There has not been a research of this kind, not at present, in the Maltese Islands. Therefore, comparison of differences and similarities of previous studies was impossible at this time. The interest to carry out this research stems from the fact that there are a lot of people with diabetes complications in our society and in different wards at St. Luke's hospital. Complications as stated above and its incapacitating effects on the individual and the final burden it exerts on the nation's economy were considered. This drew the researcher's attention to this area of study. The overall aim of this study therefore was to examine whether physical activity stimulates a generalised improvement in glycaemic control in patients with Type 2 diabetes mellitus and to evaluate the actual difficulties or obstacles encountered by patients who may not continue with physical activity among Maltese population.

2. Materials and Methods

Hundred and twenty patients regularly attending the Diabetes Clinic, St. Luke's Hospital, and aged 30 to 44 years received letters, explaining to them the exercise programme designed for people with Type 2 diabetes and requesting their participation. Only hundred patients responded and attended the first meeting prior to the exercise programme. These patients were randomly assigned into control and intervention groups.

Prior to the commencement of the exercise programme, permission was obtained from the Director of Diabetes Clinic to access the medical records of these patients. Subsequent to this, permission was also obtained from the University of Malta Ethics Committee before dispatching letters to individual patients requesting their formal consent which involved signing the letter suggesting approval and returning it in self-addressed envelopes.

2.1. Criteria for Inclusion

Eligibility criteria included age between 30 and 44 years because Type 2 diabetes mellitus commonly begins from when one is 30 years, although there have been exceptions where the disease has started much earlier. That is why this study considered including those who are 30 years with Type 2 diabetes.

Absence of serious debilitating diabetic sequelae e.g. blindness, marked neuropathy, or incapacitating renal or cardiovascular problems.

Type 2 diabetes mellitus diagnosed more than one year before this study, and registered at Diabetes Clinic, St Luke's hospital, residing in the southern part of Malta for easy access to the two exercise programmes both situated in the south of Malta.

Individuals who did not meet the eligibility criteria, or suffered from other major chronic disease in addition to Type 2 diabetes mellitus were excluded from the study.

2.2. Study Design

All participants were assessed during their first visit to establish their baseline parameters. Information was collected on a variety of issues such as demographic data, weight and blood pressure. Each subject was given investigation forms and asked to attend the Diabetes Clinic at St. Luke's Hospital to submit blood samples for the estimation of HbA1c levels, triglycrides, HDL-cholesterol, LDL cholesterol and total cholesterol. Results were then recorded on a data sheet designed for the study. Their body weight was measured to the nearest 0.1kg. Blood pressure was measured using Mercury and electronic sphygmomanometers. Readings were taken by the same person.

The exercise programme was designed to be held three times a week, that is, Mondays and Wednesdays at the Marsa Sports Complex and Fridays at the Razzett tal-Hbiberija Sports Complex, M'Scala. The Razzett tal-Hbiberija provided us with an instructor who coached us in different types of aerobic exercises including aqua-aerobics and handling of light weights in a very conducive environment. The research participants were all enthusiastic to lose weight and to bring their blood glucose levels under control. At the Marsa Sports Complex, the subjects who felt comfortable to jog did so. The others walked briskly. Those in the intervention group were advised to consult their GPs prior to starting the exercise programme to rule out any possible problems that could hinder them from participating effectively in the exercise programme. Individuals with evidence of ischaemic heart disease or other disease processes where exercise was contraindicated were excluded from the study. The subjects exercised for 30-40 minutes at the beginning. After one month of the exercise programme, most of them were exercising 50-60 minutes according to individual strength.

2.3. Protocol of Exercise Programme

Subjects participating in the exercise programme were evaluated for physical fitness by their GPs. They were also advised to visit a podologist at their respective Health Centres to rule out any possible neuropathy. Thereafter, the exercise programme commenced. Physical activity was regularly monitored by daily exercise records designed for the study. Another diary was also designed to keep records of the type of exercise they did at their own time. The exercise programme itself included jogging, brisk walking, aerobic exercises such as dancing, manipulating different weights, swimming, biking on a stationary bike and climbing stairs. Exercise groups and family support were strongly encouraged and family members or friends were also allowed to participate, but were not included in the study.

Also aerobic exercises were performed under supervision of an experienced physical therapist once weekly at the Razzett tal-Hbiberija and patients were encouraged to exercise on their own outside our normal three days per week exercise schedules and record the type of exercise in a log-book provided for them. The control group maintained their usual level of activity throughout the study.

2.4. Intervention Group

Among a random sample of fifty diabetics identified for the study as having type 2 diabetes, thirty-four gave permission to join the exercise programme and for their medical records to be reviewed while participating on the exercise programme. The intervention group was assessed before the commencement of the exercise programme, by taking their baseline measurements. Subsequent measurements were taken on two separate occasions three months apart. The blood glucose levels were monitored three times a week before each exercise session with the Glucotrend 2 glucometer and together with the blood pressure using a sphygmomanometer supplied to us by Roche Pharmaceutical Company, Germany and Vivian's Commercial, Malta, respectively. At the end of the exercise programme each subject in the intervention group including those who dropped out at the end of the exercise programme were given questionnaires to fill. The structure of these questions was mainly based on their health beliefs regarding what are the sources of hinderances and improvement of their diabetes condition.

2.5. Control Group

Among the fifty patients in the control group who consented to be assessed every three months, either in the comfort of their own home or at the Diabetes Clinic, twenty-three declined while twenty-seven agreed to be followed up. The control group was matched for age and duration of diabetes with the intervention group at the start of the study.

2.6. Parameters Measured and Code Names

Parameters, such as the glycosylated haemoglobin (HbA1c), weight, cholesterol, low density lipoprotein cholesterol (LDL-C), high density lipoprotein cholesterol (HDL-C), triglycerides, and blood pressure (Bp), were monitored every three months during the exercise programme. Blood pressure, random blood glucose (RBG), and weight were checked every week to encourage improvements in exercise.

The measurements were recorded for three consecutive periods from baseline, designated as, for example, "HbA1c1" or "weight1". The period between the months of May and July was designated as, for example, "HbA1c2" or "weight2" as the case may be, and finally from August to November as, for example, "HbA1c3" or "weight3". Other parameters are written in this format for the sake of clarity, for example, cholesterol ($chol_1$), low density lipoprotein (LDL_1), high density lipoprotein (HDL_1), triglycerides1, systolic1 and diastolic1, etc. In the same manner, measurements taken at the end of July would be represented as, for example $HbA1c_2$, Chol2, HDL2, LDL_2, $Trigly_2$ and $weight_2$. Finally, measurements taken at the end of November are likewise put in this form: $HBA1c_3$, $Chol_3$, HDL_3, LDL_3, $Trigly_3$ and $weight_3$.

2.7. Statistical Methods

Sample t-tests were used to compare two independent groups such as cholesterol, weight and HbA1c, LDL, HDLs and triglycerides of the intervention and control groups. The homogeneity of the experimental group was tested using an analysis of variance (ANOVA) on variables measured after the exercise programme. Control and intervention group were determined by a two-way repeated measure of ANOVA on variables measured during the exercise programmes. The differences between measurements obtained pre- and post training period in each group were compared using the students't test. A level of $p < 0.005$ was selected to indicate significant differences between mean values. Using descriptive statistics, one-way ANOVA was used to analyse questionnaire data among intervention group.

3. Results

3.1. Demographic Variables

Analysis of the demographic data revealed the following: subjects ranged in age from 30 to 44 years with a mean age of males 40.3 years and females with a mean age of 35.9 years. The average length of time since diagnosis of diabetes was 3.1 years, with a range of 1.0 to 10.0 years. The number of males who participated in the intervention group was fifteen and the number of females was nineteen. Nineteen subjects (55.9%) were managing their diabetes with oral hypoglycaemics such as metformin, glibenclaimides and exercise.

3.2. Glycaemic Control and Exercise

The exercise protocol consisted of a seven month supervised period except during the middle month of September. Exercise was performed three times per week and collection of data was continuous throughout the period of exercise. The Intervention group participated in the exercise programme while the Control Group did not. However, the Control group was also monitored every three months like those in the Intervention group at three months interval.

During analysis of the parameters the mean differences of the HbA1c at baseline between the Control and Intervention group was not statistically significant. At baseline, there was no significant difference between the Control and Intervention groups in all the parameters measured except the HDL which was significantly high, p=0.003. HbA1c level with p=0.061, weight with p=0.001, total cholesterol with p=0.59, triglycerides with p=0.671, low density lipoprotein (LDL) with p=0.022 and high density lipoprotein (HDL) with p=0.003. The absolute change of HbA1c with the Intervention group was almost at par with the Control at baseline. The mean of the Intervention group was 8.97 and the Control group was 9.88 with mean difference of 0.91 and p=0.061. This suggests that there was no significant difference between the two groups before the exercise programme was initiated.

At the end of July, the participants underwent laboratory investigations to establish their glycosylated haemoglobin level and their lipid profile and blood pressure, the results showed remarkable improvements in total cholesterol over the three month period of exercise with a mean difference (MD) of 4.72 (p=0.030). There was a significant difference between HbA1c of intervention group and that of the control group with a mean difference (MD) of 8.33 (p <0.001). Weight was significantly reduced with MD=8.13 and (p =0.003). The difference in HDL cholesterol was not significant at 0.005 MD= -0.18 however, there was an increase which indicated an improvement (p=0.020). Triglycerides and LDL cholesterol were not also significant with MD=0.05 (p =0.852) and MD=0.49 (p =0.046 respectively).

The significant differences indicated in the HbA1c and weight emphasize the importance of exercise in the control of glycaemia and weight. During this supervised exercise period, the means of different parameters in the Intervention group were gradually decreasing. Also a decrease was noticed in the means of the Control group parameters like the HbA1c and LDL cholesterol while the other parameters slightly increased as shown in Table 1.

Table 1. *The mean difference of parameters between Intervention and Control Groups*

Baseline		**May to July**	**August to November**
HbA1c (1 – 2)			
Control/mean	9.88	9.86	10.27
Intervention/mean	8.97	8.33	8.11
Mean difference	0.91	1.52	2.17
p-value	.061	.001	.000
Weight			
Control/mean	93.47	92.74	93.52
Intervention/mean	88.29	84.62	85.97
Mean difference	5.17	8.13	7.55
p-value	.019	.003	.001
Cholesterol			
Control/mean	5.41	5.47	5.59
Intervention/mean	4.73	4.72	4.71
Mean difference	0.68	0.75	0.89
p-value	0.59	.030	.008
Triglycerides			
Control/mean	1.87	1.96	2.00
Intervention/mean	1.99	1.91	1.92
Mean difference	-0.12	0.05	0.08
p-value	.671	.852	.765
LDL			
Control/mean	3.57	3.45	3.58
Intervention/mean	2.94	2.95	2.98
Mean difference	0.62	0.49	0.60
p-value	.022	.046	.017
HDL			
Control/mean	1.16	1.21	1.29
Intervention/mean	1.39	1.39	1.41
Mean difference	-0.23	-0.18	-0.12
p-value	.003	.020	.203

The reading of the parameters of Intervention group at the end of November shows that there was a significant decrease in HbA1c and weight when compared with the Control group. There was a progressive decrease in these parameters at the end of November and it was significant. HbA1c with MD=8.11 and P<0.005, weight increased slightly from the previous reading with MD=7.55 and P=0.001, total cholesterol at the end of November was MD=0.89 and P=0.008, although it was not statistically significant but it showed a strong relationship between exercise and cholesterol reduction.

The triglycerides show a slight decrease between the months of August and November when compared with the triglycerides of the month of July. Triglyceride of MD=0.08 and P=0.765. The LDL cholesterol also increased from August to November period with MD=0.60 and P=0.017. This difference is not statistically significant; however, it suggests that lack of exercise would increase LDL cholesterol. The HDL cholesterol was significantly low at baseline between the Control and Intervention group and made a gradual increase from baseline to the end of the seven month period of exercise in the intervention group. This increase in HDL of the participants, according to the finding of Framingham Heart Study (Daniel et al, 2003) may imply that there was a significant coronary risk reduction in this group.

Considering the HbA1c of both groups, it shows that while the mean of HbA1c of the Control group increased, the mean of the Intervention group decreased. There was a steady increase in the HbA1c of the Control group throughout the seven month period of the exercise programme. This unexpected increase is hard to interpret but it may suggest that lack of exercise in the Control group might have led to continuous deterioration in glycaemic control of this group. According to the results shown in Table 1, from the months of May to July, progressive improvements were noticed throughout the parameters in those that were significant and those that were not. It could be that the zeal for exercise was high in participants at first and they were motivated to embrace exercise as a panacea to alleviating hyperglycaemia and possibly, delay the onset of any diabetic complication. It was conducted under strick supervision, which also ensured encouragement and compliance to the exercise time table.

An exercise of this intensity (that is between 30 minutes to 60 minutes) improved the parameters in the Intervention group, suggesting that the exercise intensity was sufficient, at least to a certain degree. In this study, there was deterioration in glycaemic control in the Control group despite changes in HbA1c in the Intervention group, suggesting a positive effect of exercise training in protecting against deterioration in glycaemic control. Improvements in total cholesterol, weight, HDL-cholesterol and triglycerides levels after the first three months support the efficacy of supervised exercise programme in Type 2 diabetes mellitus treatment regimens.

Studies such as (Barnard et al, 1994,) have stated that combination of diet and exercise helps at improving glycaemic control. However, the present study did not include dietary intervention as a means of encouraging weight loss or improving glycaemic control. Participants decided at their own discretion whether to increase or decrease the amount of food they eat. This may in part be attributed to the gradual increase in the overall parameters during the second phase of the exercise programme (August to November). Yet, there were significant differences in HbA1c ($p<0.005$) and weight ($p=0.001$). This further reinforces the importance of exercise of any intensity in these two parameters. The difference in cholesterol was not significant but the improvement was remarkable ($p= 0.008$) which indicated that the difference is not big in magnitude.

The improvement in glycaemic control correlated strongly with consistence in exercise programme as shown in Graph 2 $(r = 0.333)^2$. The recommendation that exercise training can be used as a therapeutic means to lower blood glucose levels in Type 2 diabetes mellitus stems primarily from the fact that exercise has pronounced effects upon the metabolism of glucose.

This study demonstrates the potential feasibility and effectiveness of a supervised exercise programme regarding body weight, blood pressure and total cholesterol reduction and improvement in glycaemic control.

Table 2. *Blood Pressure measurements over seven months period of the exercise programme*

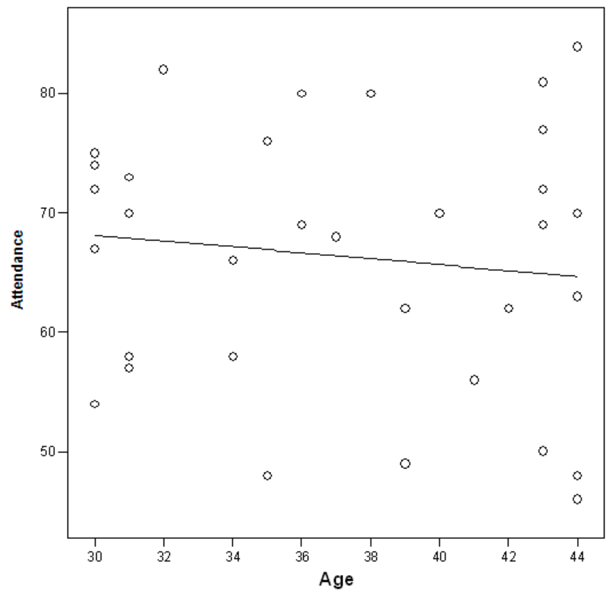
	Lower Bound	Mean	Upper Bound	Confidence Interval
$Systolic_1$	120.3	121.9	123.9	121.9 ± 1.9
$Diastolic_1$	84.6	87.4	90.3	87.4 ± 2.8
$Systolic_2$	141.5	147.9	154.2	147.9 ± 6.4
$Diastolic_2$	81.8	84.9	87.9	84.9 ± 3.0
$Systolic_3$	145.2	151.8	158.4	151.8 ± 6.6
$Diastolic_3$	86.6	86.6	89.6	86.6 ± 3.0

Table 2 represents the mean of blood pressure over the seven months period of the intervention group. At baseline, the systolic blood pressure lower bound was 120.3 mmHg, the mean systolic blood pressure was 121.9 mmHg, the upper bound was 123.9 mmHg, and the confidence interval was 121.9 ± 1.9. The diastolic blood pressure lower bound was 84.6 mmHg, the mean diastolic blood pressure was 87.4 mmHg, the upper bound 90.3 mmHg and the confidence interval was 87.4 ± 2.8 mmHg. When these figures were compared with the readings of blood pressure taken after three months of exercise as shown on Table 2. The systolic blood pressure seemed to increase to 141.49 mmHg while the diastolic blood pressure decreased to 81.82 mmHg. The differences in mean between the two types of blood pressure were huge. The mean of the systolic pressure was 147.85 mmHg while the diastolic blood pressure was 84.85 mmHg. During the third measurements of blood pressure at the end of November, an increase was noticed in both systolic and diastolic pressures. The systolic blood pressure increased to 145.22 mmHg and diastolic blood pressure became 86.58 mmHg. The same reason which affected other parameters could also possibly explain this increase.

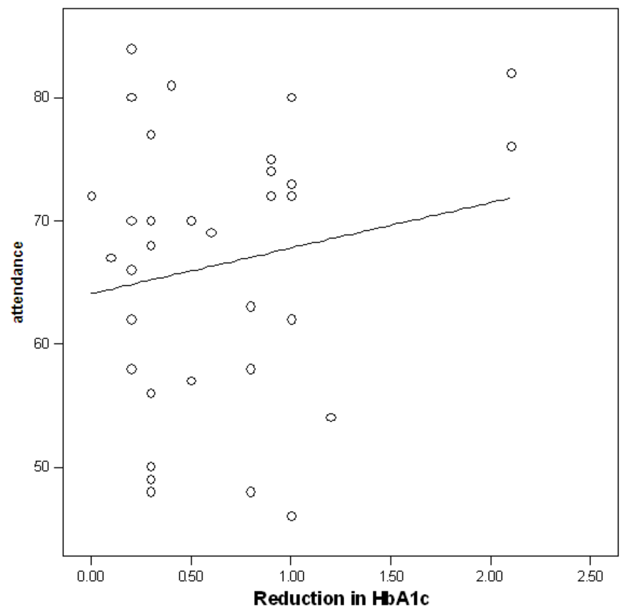
3.3. Analysis of Attendance Records

The period of exercise lasted for seven months. The total duration of the exercise programme was of 84 sessions. The highest attendances recorded were 82 sessions by one person, followed by 81 sessions by another person. 80 sessions were attended by two persons. The researcher cannot truly confirm these figures given that there were interruptions during the month of September and when it was declared that people remain indoors, some of the subjects might have marked them present in the log book given to them. The lowest attendances recorded were on subjects attending 46 and 48 sessions, which were almost half of the exercise sessions.

Subjects from various age groups were involved in the exercise. The number of attendances was not affected by age, as shown in the graph. There is no trend across the graph. There were as many older people as there were younger people who attended.



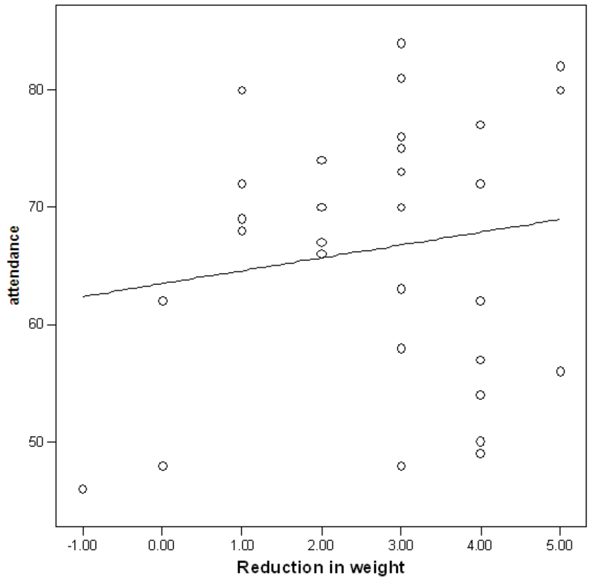
Graph 1. *Relationship between Attendance and Age (r = 0.484)*



Graph 2. *Relationship between Attendance and HbA1c (r = 0.333).*

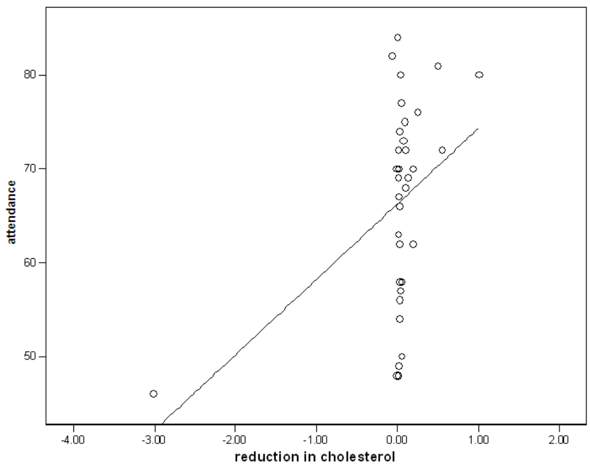
The impact of attendance on other parameters such as Hba1c, weight and cholesterol suggests that the more the subjects attended the exercise training programme, the more there was an improvement in glycaemic control. For example, this is a graph of HbA1c and attendance. The differences between HbA1c1 – HbA1c2 were collected and plotted against attendance. From the graph, it can be inferred that the more exercise the subjects attended, the more there was a reduction in HbA1c level.

Similarily, when the differences in weight (weight1 – weight2) were obtained and plotted against attendance, it was also seen that the more exercise the subjects were involved in, the more the decrease in weight.



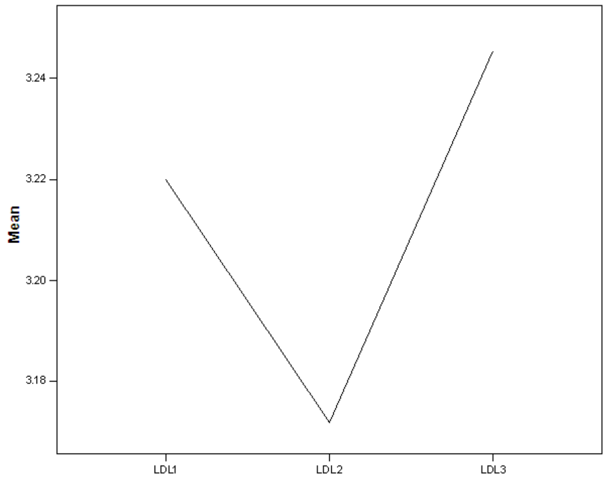
Graph 3. *Relationship between Attendance and Reduction in weight (r =0.389)*

The difference in the graph of cholesterol1 - cholesterol2 showed also that increase in exercise through regular attendance also result in decrease in cholesterol level. This correlation is significant at the 0.05 level.

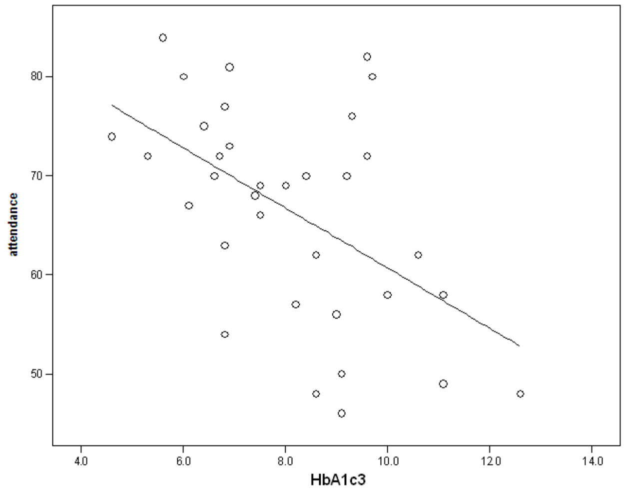


Graph 4. *Relationship between Attendance and Reduction in Cholesterol (r = 0.425)*

The graph of LDL over the 7 months period showed that there was a decrease after three months of exercise (LDL2) and an increase again during the next three months commencing from August to November (LDL3).



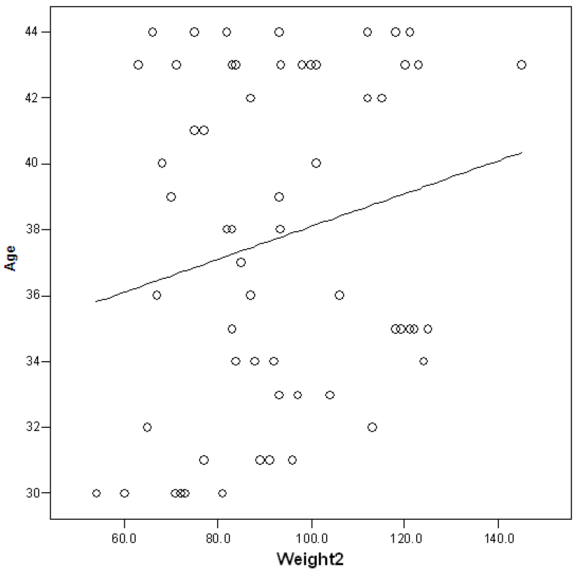
Graph 5. *Comparison of LDL from the beginning of Exercise in May to the end of November*



Graph 6. *Relationship between attendance and HbA1c from May to November*

These graphs show the impact of maintaining exercise regimens in the control of HbA1c, weight and other parameters in the improvement of glycaemia and reduction in weight. The findings from these results would be discussed in the next chapter. Besides, as could be seen from the graphs subjects who were older had increase in weight and HbA1c, it could mean that older subjects might have had relatively greater defects in beta cell responsiveness to physical activity and also decrease metabolic rate in weight reduction.

The graph shows that as the attendance increases, the HbA1c level over the seven months period also decreases.



Graph 7. *Relationship between age and weight*

This graph shows that subjects who are older in age had also more weight.

4. Discussion

4.1. Limitations of the Study

This study of impact of physical activity on the glycaemic control of Type 2 diabetic adults among the Maltese population should have involved selecting a nationally representative sample from the age groups in question. This would have meant using national diabetes register as a sampling frame, and using a computer generated list of random numbers to select a random sample. The sample size would ideally have been larger. Due to the time limits of this research project and the limitations in terms of human and material resources, this method was not considered feasible.

4.2. Impact of Exercise on Glycaemic Control as Indicated by HbA1c

In this study, subjects in the Intervention group with Type 2 diabetes mellitus benefited from an exercise training programme of moderate intensity. The zeal for exercise was high during this period. There were remarkable changes in parameters as observed in Table 1. These changes occurred despite the finding that there was not a corresponding improvement at the end of November when the final measurements were made. During the period of May to July, the Intervention group HbA1c values and weight were significantly reduced ($p<0.005$) in the Intervention group when compared with the control group, suggesting that exercise has an impact in the glycaemic control of Type 2 diabetes mellitus. These findings agree with those of the American Diabetes Association (1997), the American College of Sports Medicine (ACSM) (1997), Ronnemaa et al (1986), and Schneider et al. (1984). Normand et al. (2001) suggest that a reduction in HbA1c of this magnitude is clinically significant.

The exercise programme was well supervised during the first three months and each subject completed at least forty six out of a total of eighty four sessions of training. The improvement in HbA1c, weight and lipid profile was greatest for subjects who participated more in the exercise programme as indicated by attendance records, and there was a significant correlation between improvement in HbA1c, lipid profiles and regular exercise in the first three months. The greater the number of times attended for exercise the more there was improved HbA1c, weight loss and lipid profile. According to DeFronzo et al (1983) and Wahren (1979), they believe that a more likely explanation for the effects of training on HbA1c and lipid profile arises from a consideration of the changes in pattern of fuel utilization that occur during exercise in diabetic subjects. Vramic & Berger (1979) argue that in the presence of low plasma insulin concentrations, as exercise intensity increases, oxidation of muscle glycogen increases and plasma glucose becomes more important in energy supply when compared with fat (Saltin and Karlsson 1971), thus acutely favouring glucose utilization in the Type 2 subjects. Piehl (1974) asserts that prolonged improvement should also occur between exercise bouts, since muscle glycogen stores used during exercise must be replenished from plasma glucose over the next 24-48 hours. Therefore, the weekly lowering of plasma glucose by acute exercise may have resulted in the observed improvements in HbA1c. These changes in turn may have resulted in the improvement in glycaemic control observed during the end of training in November.

Relative to this, Kelly & Goodpaster (2001) contend that patients with Type 2 diabetes mellitus, following aerobic exercise has a modest positive impact on glycaemic control. They point out that the impact of exercise training on blood sugar, weight and lipids may be relatively small, but generally positive. Contrary to this, James et al (1984) in their previous study demonstrated that moderate exercise training of middle-aged patients with Type 2 diabetes mellitus subjects over 14-34 weeks did not improve fasting plasma glucose levels or oral glucose tolerance.

During the months of August to November the decrease in HbA1c was not accompanied by loss in weight. Normand et al (2001) in their previous study found that the differences in HbA1c found between the exercise group and control group after treatment, were not mediated by differences in weight loss, exercise intensity or exercise volume. They contend that exercise does not need to reduce body weight to have a beneficial impact on glycaemic control. Exercise training decreases hepatic and muscle insulin resistance and increases glucose disposal through a number of mechanisms that would not necessarily be associated with body weight changes (ibid). The mechanisms were extensively reviewed by Ivy et al (1999) and include increased post receptor insulin signaling (Dela et al 1993), increased glucose transporter protein and messenger RNA (Dela et al, 1994), increased activity of glycogen synathase (Ebeling et al, 1993), and hexokinase (Coggan et al, 1993), decreased release and increased clearance of free fatty acids (Ivy et al, 1999), increased muscle glucose delivery due to increased muscle capillary density (Coggan et al, 1993) and changes in muscle composition favouring increased glucose disposal (Andersson et al, 1998).

In addition, Vanninen et al (1992) advocate that the beneficial effects of exercise programmes are often underestimated because changes in body weight may not necessarily reflect improvements in body composition. In the present study, the intervention group produced no statistically significant reduction in body weight from August to November but there was a reduction in HbA1c. This supports the findings of Normand et al (2001), Drexel et al (1972) and Bogardus et al (1984) that exercise does not need to reduce body weight to have a beneficial impact on glycaemic control. However, there are other possible explanations for this lack of change in weight. First, the exercise training from August to September was of relatively short duration due to the interruption by storm when compared with May to July. Second, exercise participants might have reduced their weekly physical activities during this break, since they were unsupervised, partially counterbalancing the increased expenditure of energy from the exercise programme. Third, Intervention group subjects might have increased their food intake during the break period. This increase was noticed in all parameters across these months except the HbA1c and HDL. The increase in HDL during this period may be considered as positive.

Table 3 is showing number of attendances achieved by different age group ranging from 30 years to 44 years.

Table 3. *Number of attendances achieved by different age group*

Age	N	Attendance	Std. Deviation
30	6	69.00	7.849
31	4	64.50	8.185
32	1	82.00	.
34	2	62.00	5.657
35	2	62.00	19.799
36	2	74.50	7.778
37	1	68.00	.
38	1	80.00	.
39	2	55.50	9.192
40	1	70.00	.
41	1	56.00	.
42	1	62.00	.
43	5	69.80	11.987
44	5	62.20	15.818
Total	34	66.41	10.832

Confounding variables that may contribute to the statistical differences on the subsets of benefits and barriers to exercise may be identified within the demographic data. It is feasible that the younger age group who were diagnosed 1-3 years seemed to be more keen to exercise (age = 31, attendance sessions = 82) while the older age group, diagnosed more than ten years were less keen to exercise, (age = 44, attendance sessions = 62.2), making adherence to a prescribed exercise regimen more difficult. Additionally, the older individuals may have less social support as identified by Quakenbush et al (1996) that may need additional support and encouragement to assume and continue their daily self- management responsibility of this disease process. It is noteworthy that older Maltese men and women facing progression of the disease, without recurrent reinforcement of the value of exercise within the treatment of diabetes, may perceive less benefit or value in the role of exercise in the long term. Another additional variable that may confound the results is the difference in pharmacological treatment plan. For instance, some of the subjects were receiving oral hypoglycaemic agents, cholesterol lowering drugs and anti-hypertensives.

5. Conclusion

Although the individual trials on the effects of exercise in patients with Type 2 diabetes have had partially conflicting results, the current study suggests that exercise training reduces HbA1c by a degree that would be expected to reduce the risk of diabetic complications significantly. The studies reviewed for this research did not find significantly greater weight loss in the Intervention group compared with the Control group. This literature corresponds to the findings of the present study in the third phase of measurement. Therefore, exercise should be viewed as beneficial on its own, not merely as an avenue to weight loss especially where dietary intervention is not involved. This is because exercise increases the energy expenditure, which, when combined with diet can lead to body weight loss and decreased body fat content. Future research could include longer interventions with better quantification of body composition changes. Normand et al (2001) suggest that more accurate measures of body composition such as computed tomography, magnetic resonance imaging or hydrostatic weighing would be desirable in future studies to precisely measure changes in body composition. In the interim, the outcome of this study adds support to the idea that exercise is a cornerstone of improving glycaemic control in Type 2 diabetes mellitus.

Exercise therapy is potentially effective as an adjunct to other modes of treatment in early Type 2 diabetes mellitus. Further studies are recommended to elucidate how the metabolic effect of physical activity and Type 2 diabetes are modulated by duration of diabetes and intensity of exercise on the glycaemic control and lipid profile. Trovati et al (1984) point out that as far as Type 2 diabetes is concerned regular exercise can be recommended as part of daily management. This should be done in addition to and not in replacement of diet and, if necessary, pharmacologic treatment. In conclusion, the results provide evidence that regularly performed exercise can be effective in lowering peripheral blood glucose sufficiently to improve HbA1c in Type 2 diabetic patients.

6. Recommendations for Practice

A strong, multi-sectoral committee should be set up to assume the overall responsibility for the planning and implementation of health education and health promotion activities related to physical activity on people with Type 2 diabetes mellitus. This should include representatives from the health division and health promotion department, Non-Governmental Organizations (NGO) and youth organizations. The joint effort of these groups would result in an effective and strong resolve to help people with Type 2 diabetes mellitus.

This committee should initiate a well-sustained exercise programme campaign targeted at the general population of Type 2 diabetic people in the Maltese Islands and should include the use of mass media and the participations of spouses, partners, friends and relatives. A possible initiative could be to lobby for financial support from the government to underpin this project.

This campaign might not only provide information about the improvement of glycaemic control but also address the issue of people who are genetically predisposed to diabetes and initiate a prevention programme for this group.

This prevention programme should start at earlier stage to prevent or delay the onset of diabetes.

This programme should ensure that while exercise is the best option to delay the onset of Type 2 diabetes, those who would be reluctant are made aware of the importance of consistent exercise.

The exercise programme should also help people with Type 2 diabetes to increase their control over the management of their disorder.

There should be a school-based programme to identify, train and supervise a number of nursing students to have an active role in the prevention strategy programme for people who are genetically predisposed or who enjoy sedentary lifestyle.

General practitioners should be given the appropriate support and training to be able to meet the expectations of patients with Type 2 diabetes who perceive them as the preferred source of knowledge about the disease condition. In particular they should be encouraged to create diabetes friendly clinics supplied with diet and exercise orientated information leaflets.

The Diabetes Clinic at St Luke's Hospital should be strengthened, especially in terms of human resources so as to make it more accessible for people with Type 2 diabetes. Such outreach should include establishing a database for diabetic patients in the Maltese Island in the long run.

7. Recommendations for Further Research

A larger scale and better funded research study on the impact of physical activity on the glycaemic control of Type 2 diabetic patients among the Maltese population, representative of all Type 2 diabetics in Malta is strongly recommended.

Qualitative research should be carried out to determine the principal factors which are preventing Maltese Type 2 diabetic patients from engaging in active exercise practices.

Future research on the effectiveness of exercise in Type 2 diabetes mellitus should attempt to include assessment of additional cardiovascular risk factors beyond measures of glycaemic control and lipid profile measures.

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