Skin microvascular reactivity in children and adolescents with type 1 diabetes in relation to levels of physical activity and aerobic fitness

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This is an electronic version of an article published in Psychology, Health and Medicine, 12 (3). pp. 353-363. ISSN 1354-8506. © 2007 Taylor & Francis.

Psychology, Health and Medicine is available online at:
http://www.tandfonline.com/doi/abs/10.1080/13548500600975446

Physical activity and psychological well-being in children with Type 1 diabetes

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Running title:

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Abstract

Physical activity and psychological well being contribute to positive lifestyle and well being in youngsters who have Type 1 diabetes. The aims of this study were to objectively assess the physical activity levels of children with Type 1 diabetes, and investigate associations between physical activity levels, psychological well-being and HbA_{1c}. Thirty-six children, mean age 12.8 years, participated in the investigation. Physical activity was assessed using heart rate monitoring over four days. Children further completed the Diabetes Quality of Life for Youths Questionnaire, the Physical Self-Perception Profile for Children, and the Self-Efficacy for Diabetes Scale. Routine outpatient HbA_{1c} measurements were recorded. There were no significant associations between psychological well-being and physical activity, or HbA_{1c} and physical activity, thus suggesting physical activity does not directly relate to psychological well-being in children with Type 1 diabetes. It may be that the effect of physical activity differs from that in children without Type 1 diabetes because of the place of physical activity within diabetes management and the need to balance this with insulin dosage and dietary intake to maintain blood glucose levels.

Key words: Children, HbA_{1c} , physical activity, psychological well-being, Type 1 diabetes

Introduction

The importance of psychological well-being alongside indicators of physiological health is increasingly being recognised within children's Type 1 diabetes management. This can be seen by a shift from using HbA_{1c} as *the* ultimate outcome measure to a focus on multiple and wider outcome domains (Urquhart Law, 2002). Concomitant with this has been a proliferation of studies investigating psychosocial effects of diabetes management. However, one aspect of diabetes management that has not been investigated in this respect is physical activity. As part of the diabetes management triad, physical activity must be balanced with energy intake and insulin dosage in order to maintain desired blood glucose levels. This linkage of physical activity to disease management may alter its psychological impact compared to non-diabetic children. In addition, children typically engage in unplanned physical activity (Welk et al., 2000), which by its nature is hard to predict when calculating appropriate insulin dosages and dietary intake, and can cause blood glucose levels to increase or decrease depending on insulin levels at the time. These consequences make the experience of physical activity for children with Type 1 diabetes unique psychologically as well as physiologically.

The incidence of depression in children with Type 1 diabetes is two to three-fold that of children without diabetes (Kokkonen et al., 1997). Similarly Grey at al. (1995) found that two years post diagnosis children with Type 1 diabetes had significantly higher depression scores than their peers without diabetes. Kovacs et al. (1995) followed a group of children over first five years following diagnosis and found 27% had an episode of a specific psychiatric disorder during this period, with major depression and conduct disorders being the most common.

In the non-diabetic population there is now fairly strong evidence of a positive association between physical activity and psychological health. Calfas and Taylor (1994) found physical activity was associated with reductions in depression, anxiety and stress and increased self-esteem. A recent Cochrane review concluded that exercise may be an important measure in improving children's self-esteem, although it was noted that the quality of the data available was low (Ekeland et al., 2004). These findings have been endorsed in a position statement on physical activity and young people published by the Health Education Authority (1998) and more recently in a report from the Surgeon General in the UK (Department of Health, 2004).

The only two studies identified which examined this relationship in people with Type 1 diabetes were on adults; both found a positive association between physical activity and psychological well-being. Zoppini et al. (2003) reported that those who were physically active had significantly greater satisfaction with life than those who were inactive, although there were no differences in diabetes impact or diabetes related worries. An earlier longitudinal study (Stewart et al., 1994) showed that in a group of adults with Type 1 diabetes, those rated as high active perceived themselves as having significantly greater psychological health and physical functioning at two year follow up compared to a low active group. A study which investigated the exercise beliefs of 30 adolescents with Type 1 diabetes (Loman & Galgani, 1996) found the majority strongly agreed or agreed that exercise made them feel good and was a way to have fun with other people. However, no published studies were identified which actually measured physical activity and psychological well-being in children with Type 1 diabetes.

Although there has recently been an increased focus on psychological outcomes for children with Type 1 diabetes, metabolic control remains an important outcome of disease management. There has been limited research investigating the relationship between physical activity and metabolic control in children. A recent study using accelerometers assessed physical activity in 26 adolescent girls with Type 1 diabetes and found no association between these measurements and HbA_{1c} (Sarnblad et al., 2005). This concurred with the findings of previous cross-sectional research which investigated self-reported physical activity and metabolic control in children with Type 1 diabetes (Bennett Johnson et al., 1990; Hanson et al., 1996; Loman & Galgani, 1996). Therefore the evidence to date suggests that there is no association between physical activity and metabolic control, although only one small scale study has assessed physical activity objectively. Data from exercise intervention studies are equivocal in relation to the effect of increased exercise participation on metabolic control in children (Campaigne & Lampman, 1994), but an increase in insulin sensitivity has been shown in adolescents with Type 1 diabetes (Landt et al., 1985).

Thus, there is evidence for a positive association between physical activity and psychological health in children generally, but it is not yet clear whether this relationship holds true in children with Type 1 diabetes. Limited evidence from adult studies suggests it may, however it may also be that the relationship is altered because of the sporadic physical activity patterns engaged in by children and the resultant interaction with blood glucose levels. If the association between exercise and psychological well-being in children with Type 1 diabetes is found to mirror that of the general population it may be possible to use exercise as an intervention for those suffering from depression or other psychological disorders. The present study aimed to investigate associations between objectively assessed physical activity and both psychological well-being and HbA_{1c} in children with Type 1 diabetes.

Methods

Participants

Children were recruited from two NHS hospitals in the Northwest of England. Inclusion criteria were age 9-15 years at recruitment, and diabetes duration greater than two years. Nine years old was the minimum age to ensure that children were able to complete the psychological questionnaires, and 15 years old was the maximum age as children move to the adult clinic after this age. Consent was obtained from parents or guardians. Eighty-three children were invited to participate, 46 consented. Of these ten subsequently dropped out leaving 36 participants (18 boys, 18 girls). Participants' mean age at data collection was 12.8 (± 2.1), mean duration with Type 1 diabetes was 5.9 (± 3.0) years. Due to ethical constraints no data were available on those children who declined to participate or those who withdrew. Reasons given anecdotally for non-participation were distance from home to the study laboratory, or not wishing to wear a heart rate monitor for four days including time at school. Ethical approval for the study was obtained from the two relevant NHS trusts and the university ethics committee.

Measures

The Diabetes Quality of Life for Youths Questionnaire (DQOL-Y) (Ingersoll & Marrero, 1991) consists of three subscales, using Likert scale measurements: satisfaction with life, disease impact (both rated on 5 point scales) and disease related worries (rated on a 6 point scale), and a single item overall self rating of health (4 point scale). Ingersoll and Marrero found the scale to have high internal consistency for a sample aged 11 to 22 years, Cronbach's Alpha values were 0.85, 0.83 and 0.82 respectively. Internal consistency was also high with the present sample, Cronbach's Alpha values of 0.86, 0.87 and 0.83 respectively were found. Values of 0.7 are regarded as satisfactory for comparing groups (Streiner & Norman, 1995) although values above 0.5 may be considered acceptable (Eiser & Morse, 2001).

The Self Efficacy for Diabetes Scale (SED) (Grossman et al., 1987) evaluates youngsters' perceptions of their personal ability or power in diabetes and related situations. Three subscales, using 6 point Likert scale measurements, assess differing levels of generality in self-efficacy beliefs, self-efficacy for diabetes specific situations (SED-Diabetes), self-efficacy for medical situations (SED-Medical) and self-efficacy for general situations (SED-General). An overall total score is also calculated (SED-Total). Grossman et al. (1987) found Kuder Richardson co-efficient alphas on a sample aged 12 to 16 years were all acceptable (SED-Total 0.90, SED-Diabetes 0.92, SED-Medical 0.70, SED-General 0.60). Cronbach's Alpha values with the present sample were calculated as SED-Total 0.88, SED-Diabetes 0.84, SED-Medical 0.60, SED-General 0.58.

The Physical Self-Perception Profile for Children (PSPP-C) (Whitehead, 1995) assesses global self-worth (GSW), physical self-worth (PSW), and four subdomains of PSW; sports competence, attractive body competence, strength competence and condition competence. Items are rated on 4 point Likert scales. Confirmatory factor analysis with a sample of 754 children aged 8-12 years supported the factorial validity of the scale with this age group (Welk & Eklund, 2005). In the present sample Cronbach's Alpha values were calculated as GSW 0.89, PSW 0.86, sports competence 0.85, attractive body competence 0.91, strength competence 0.86 and condition competence 0.79.

Physical activity was assessed using heart rate monitoring Polar Sports Tester systems (Polar Sportstester, Kempele, Finland). A lightweight transmitter is attached to the child's chest using either an elasticated belt or 50 mm diameter Skintact foam ECG electrodes. This picks up the child's heart rate and transmits a signal via radiowaves to a receiver worn on the wrist. The system can be worn during all normal activities without altering usual physical activity patterns. Treiber et al. (1989) have shown this method to have good validity in children aged 5 to 10 years and it has been widely used in physical activity surveys of young people (Armstrong et al., 1990; Atkins, 1998).

Intra-individual variability should be considered when assessing habitual physical activity. A multiple day intraclass correlation of .80 is usually desired to maximise the ability to detect relationships with other variables (Traub, 1994). Baranowski and de Moor (2000) found that using an index which controlled for variability across individuals in resting heart rates reduced the number of days of recording necessary to obtain this reliability. They reported that using this index between 1.9 and 6.2 days of heart rate data were necessary to obtain a multiple day intraclass correlation of .80 on heart rate data from 5-7 year old children with 12 hours of heart rate data per day. No similar analysis was located for older children. In the present study physical activity was recorded for four days. Armstrong et al. (1990) compared physical activity of children aged 11 to 16 years on week and weekend days and found no significant differences, in the present study it was logistically easier to visit children's homes during the weekends. Therefore physical activity was monitored for 2 week and 2 weekend days. Resting heart rate was monitored during one night.

HbA_{1c} was measured using DCA 2000 analysers, values were taken from clinical records. The HbA_{1c} value used was the first measurement taken in the outpatient clinic after the heart rate monitoring took place. However, where this was more than 3 months after heart rate monitoring the previous measurement was used, if this was within 6 weeks. All participants had an HbA_{1c} value within these criteria. The average time between monitoring and HbA_{1c} measurement was 39.2 ± 24.4 days (mean ± SD).

Procedure

Psychological questionnaires were completed during a visit to the study laboratory. To collect heart rate data, a researcher visited each child's house just after they got up in the morning to attach the monitor and asked the child to wear it until they went to bed that night. To obtain a night recording the child left the monitor on when they went to sleep on one of the four days. The researcher returned the following morning to collect the monitor and, if necessary, attach a new one. If any of these data files were not complete, for example due to the transmitter becoming disconnected from the electrodes, or the child stopping the recording by accident, the child was asked if they would be happy to repeat the recording procedure.

Analysis

Complete physical activity data sets were not available for all participants. Data files were included in the analysis if they were 8 hours duration or longer, this would include the school day and activity getting to and from school. Using this criterion 47% (n=18) of children had complete data sets, 28% (n=11) had 3 complete files, 21% (n=8) had 2 complete files and 3% (n=2) had 1 complete file. A night recording was obtained for all participants. To allow comparison between participants, average number of minutes of physical activity per child per day was calculated. Only participants with at least two data files were included in further analyses.

Data were analysed using %HRreserve (HRmax-HRmin). Maximum heart rate was taken as the value at the end point of a VO_{2peak} test. All participants completed a test using a discontinuous treadmill protocol, data are reported elsewhere (Edmunds, 2003). Minimum heart rate was obtained from the average of the lowest 5 consecutive values during sleep. Number of minutes spent with heart rate above 50% and 75% of HRreserve were calculated. Individual heart rates corresponding to these threshold values vary but are between 135 to 148 and 168 to 174 beats per minute for children aged 6 to 18 years, and represent moderate and vigorous physical activity thresholds respectively (Stratton, 1996). Time spent above 50% HRreserve was classified as moderate to vigorous physical activity (MVPA) and time spent above 75% HRreserve was classified as vigorous physical activity (VPA).

Associations between physical activity and both the psychological variables and HbA_{1c} were investigated using Pearson Product Moment Correlation Coefficients (2-tailed). Where there were outliers, >3 standard deviations from the mean (Munro, 1997), data were analysed twice, once with them included and once with them excluded. If the significance of the results differed the distribution free Kendall's tau-b non parametric test was used in place of the Pearson. Kendall's tau-b was also used with the overall rating of quality of life as this was assessed on a 4 item ordered category scale. Due to the number of correlations conducted the level of probability considered significant was lowered using Bonferroni's adjustment. The standard level of significance $p<0.05$ was divided by the number of calculations (n=28) giving a new significance level of $p<0.002$.

Results

Descriptive statistics (mean ± SD) for the PSPP-C, SED and DQOL are presented in table 1. Males reported higher self esteem than females for all scales apart from sport competence. Self efficacy for diabetes was higher in females than males but mean scores for both genders were above the median value for the scale. Self reported quality of life was again above the median value for the scale, males reported better quality of life than females in all subscales. These gender differences were non-significant.

Insert table 1

The mean number of minutes per day spent in MVPA was 57.5 ± 32.0. The mean number of minutes spent in VPA was 9.6 ± 12.0. Sixteen children (47%) participated in moderate to vigorous physical activity for at least 60 minutes per day. Twenty-six children (76%) engaged in at least 30 minutes of moderate to vigorous physical activity per day. Boys reported higher levels of both MVPA ($t=1.74$, $p=.092$) and VPA ($t=3.03$, $p=.007$) than girls.

Insert table 2

Pearson correlation coefficients revealed no significant associations ($p<0.002$) between MVPA and self-esteem, self-efficacy, quality of life or HbA_{1c}. Similarly there were no significant associations between VPA and these variables. There were, however, trends towards greater physical activity being associated with higher ratings for components of physical self-esteem. The correlation coefficient between condition competence and MVPA was 0.38, $p=0.03$, and the correlation coefficient between it and VPA was 0.33, p=0.06. The correlation coefficient between body competence and VPA was 0.37, p=0.04. Overall health rating also showed a positive trend with physical activity, the association between it and VPA was 0.41, p=0.004.

Insert table 3

Discussion

Overall no significant associations were found between MVPA or VPA and self-esteem, self-efficacy for diabetes or diabetes quality of life. This differs from the literature on children without Type 1 diabetes where a positive association has been consistently found (Department of Health, 2004), therefore suggesting that physical activity is less influential on the psychological well-being of children with Type 1 diabetes than it is for other children. This may be a reflection of the fact that physical activity is a component of diabetes management and must be balanced with insulin dosage and dietary intake. Its role as part of disease management may reduce the extent to which physical activity is seen as fun. There may also be an element of worry involved that blood glucose levels will either be raised or lowered by the physical activity.

Positive associations have been found between physical activity and psychological well being in the two studies that have been conducted on adults with Type 1 diabetes (Stewart et al., 1994; Zoppini et al., 2003). However, the nature of physical activity in children is different to that in adults. Children tend to participate in unplanned short bursts of physical activity sporadically throughout the day, whereas adults typically participate in planned periods of continuous physical activity. The former is much more difficult for a child with Type 1 diabetes to accommodate into their management routine and maintain tight blood glucose control. Children in this study were typically taking insulin twice a day meaning that physical activity must be estimated in order for the correct dose of insulin to be taken. Finding no association between physical activity and psychological well-being in children may therefore reflect the fact that for this group participation in spontaneous physical activity does not fit easily with diabetes management and this conflict may reduce its psychological benefits.

An alternative interpretation of these data is that significant associations between physical activity and the three psychological variables measured were not found due to the sample size. Some support for this interpretation comes from the data on self-esteem that revealed a pattern of association with physical activity which was consistent with previous research and the multidimensional and hierarchical model of self-esteem (Fox & Corbin, 1989). Subdomains of physical self-esteem showed a trend towards positive associations with physical activity and there were weaker associations between physical and global self-esteem and physical activity. In addition VPA showed a relatively strong, although non-significant, positive association with overall health rating.

Similarly the DQOL-Y and SED scales may have lacked sensitivity to detect differences within the sample. There is no precedent for their use with physical activity, however, they are sensitive enough to show significant associations with other variables such as depression (Grey et al., 1998) and HbA_{1c} (Grossman et al,., 1987; Howells et al, 2002). The PSPP-C has been shown to be sensitive enough detect associations with physical activity in the non-diabetic population (Crocker et al., 2000). Examples of other generic scales that have shown significant positive associations with physical activity in non-diabetic children and adolescents are the General

Health Questionnaire, which is a measure of quality of life (Steptoe and Butler, 1996) and the physical activity self-efficacy scale (Trost et al., 2003). Given the strength of evidence supporting a positive association between physical activity and psychological well-being in children generally a larger sample of children with Type 1 diabetes should be tested to clarify the relationship, generic scales for quality of life and self-efficacy could be added to allow more detailed comparison with the non-diabetic population.

Confirmation of either of these interpretations, a non-significant or a positive association, would have implications for diabetes management. If a non-significant association is confirmed then further qualitative research should establish what the perceptions of physical activity are for children with Type 1 diabetes and what prevents the psychological benefits from participation seen in non-diabetic children. It may be possible to develop more effective motivational strategies and emphasise the fun aspect of physical activity rather than that it is part of diabetes management. In addition if control of blood glucose levels during or following physical activity is found to affect psychological outcomes then it may be possible to develop educational strategies to help children understand how their blood glucose levels will change and ways to cope with this to avoid unwanted reactions. If a positive association were found then further investigations should establish the causality of this and whether physical activity may be used as an intervention for those with mental health problems which have been shown to be more prevalent in children with Type 1 diabetes than non-diabetic children (Kokkonen et al., 1997).

Having said that mental health problems are more prevalent in children with Type 1 diabetes than the general population, the present sample appeared overall to have a healthy psychological profile. Mean levels of self-esteem were similar to normative data reported by Biddle et al (1993) for 452 British children aged 12-14 years, for example GSW was reported as 2.9+- 0.6 compared to 3.00 +- 0.79 in the present sample and PSW as 2.8 +-0.5 compared to 2.6+-0.7. The quality of life and self-efficacy scales were disease specific so comparisons with the non-diabetic population are not appropriate, however mean scores for both were above the midpoint for the scale indicating relatively high quality of life and self-efficacy. These scores were similar to recent studies on young people with Type 1 diabetes (Grey et al., 2000; Grey et al., 1998; Howells et al., 2002). There were though large standard deviations around the mean scores, suggesting that some individuals within the sample were having psychological difficulties.

The average physical activity levels found in the present sample were also encouraging. A mean of 57 ± 33 minutes of MVPA per day was approaching the current recommendation for children of one hour per day of at least moderate intensity physical activity to maintain current and future health (Department of Health, 2004). These levels were also very similar to those reported for a sample of Liverpool schoolchildren aged 9 to 13 years (Atkins, 1998), suggesting children with Type 1 diabetes have similar physical activity levels to their non-diabetic peers. However, as with psychological well-being, the large standard deviation shows that not all participants approached 60 minutes of physical activity per day. In particular girls had lower MVPA (t=1.74, p=.092) and VPA (t=3.03, p=.007) than boys. This pattern is typical of children's physical activity patterns and the lack of a control group means it is not possible to say whether the difference was greater than is found in non-diabetic children. Sarnblad et al. (2005) recently measured the physical activity of 12 to 19 year old girls with Type 1 diabetes and a comparison group without diabetes and found physical activity was lower, although not significantly, in the group with diabetes. It has been noted anecdotally by clinicians that non-adherence to insulin regimes is sometimes used to control weight, particularly by adolescent girls. This may reduce their motivation to be physically active as the salience of weight management benefits would be reduced. It would be interesting to explore this further in future research.

The mean HbA1c value of 9.7% +- 1.7 was high given the target set in the Quality and Outcomes Framework for primary care of 7.4% or less (National Diabetes Support Team, 2006). It is, however, within the range of values reported by Rosilio et al. (1998) in a review of studies on HbA_{1c} values of children with Type 1 diabetes and virtually the same as the value reported for adolescents in the conventionally treated group of the DCCT trial, 9.8%. It may reflect the fact that a number of the participants were going through puberty which is a time where diabetes control typically becomes more difficult (Rosilio et al., 1998).

Concurring with previous studies, the present investigation found no significant relationship between physical activity and HbA_{1c}. Sarnblad et al. (2005), who also failed to find a significant relationship between these two variables, commented that metabolic control is dependent on a number of different factors and so it is not surprising to find no significant association in a relatively small cross-sectional study. Exercise has been found to increase insulin sensitivity (Landt et al., 1985) which would be expected to improve metabolic control. A larger study measuring the main influences on HbA_{1c} and which allowed structural equation modelling to assess relative impacts would further understanding in this area.

These data are subject to limitations. The recruitment rate was 47%, indicating there may have been some selection bias in those who chose to participate. Ethical constraints prevented follow up questionnaires being sent to those who declined to participate. Complete heart rate data were not recorded for all participants, thus the reliability of the data as a measurement of habitual physical activity was reduced. However, an analysis of the data including only those participants with complete physical activity data sets did not alter the significance of the findings from those reported. The sample size was relatively small which limits the extent to which these findings can be generalised and increased the possibility of type 2 error. The only other published study which has assessed this relationship (Zoppini et al., 2003) had 53 adult participants, however, the validity of the physical activity data in that study is questionable, participants were grouped into active or sedentary groups but the authors do not state what measure of physical activity was used, other than that those in the active group exercised regularly two or three times a week. There have been larger studies which have assessed the relationship between HbA_{1c} and self reported physical activity (Bennett Johnson et al., 1990; Hanson et al., 1996; Loman & Galgani, 1996), it is agreed though that objective monitoring is a more valid method of assessing physical activity particularly in children (Armstrong & Welsman, 1997). The only other study which provided an objective measurement of physical activity of children with Type 1 diabetes included 26 participants with Type 1 diabetes (Sarnblad et al., 2005). Therefore although the sample is small it provides unique information and is comparable to other published studies in this area.

To conclude, this cross-sectional study found no significant association between physical activity and psychological well-being in a sample of children with Type 1 diabetes. This is different to the findings in general population studies and may be because the experience of physical activity is different for children with Type 1 diabetes. Due to the potential significance of this conclusion it requires replication in a larger sample as well as further study at the cohort and qualitative level. If the findings in this study are replicated this would have implications for how physical activity is promoted to children with Type 1 diabetes and for researchers and practitioners to better understand the experience from their perspective.

Reference list

Armstrong, N., Balding, J., Gentle, P., Williams, J., & Kirby, B. (1990). Peak oxygen uptake and habitual physical activity in 11 to 16 year olds. *Pediatric Exercise Science, 2*, 349-358.

Armstrong, N., & Welsman, J. (1997). *Young people and physical activity*. Oxford: Oxford University Press.

Atkins, S. (1998). *Physical activity, fitness and coronary risk in Liverpool schoolchildren. Ph. D. thesis.* Liverpool John Moores University, Liverpool.

Baranowski, T., & de Moor, C. (2000). How many days was that? Intra-individual variability and physical activity assessment. *Research Quarterly for Exercise and Sport, 71*, 74-78.

Bennett Johnson, S., Freund, A., Silverstein, J., Hansen, C.A., & Malone, J. (1990). Adherence-health status relationships in childhood diabetes. *Health Psychology, 9*, 606-631.

Biddle, S. J., Page, A., Ashford, B., Jennings, D., Brooke, R. & Fox, K. (1993). Assessment of children's physical self-perceptions. *International Journal of Adolescence and Youth, 4*, 93-109.

Calfas, K. J., & Taylor, W. C. (1994). Effects of physical activity on psychological variables in adolescents. *Pediatric Exercise Science, 6*, 406-423.

Campaigne, B. N., & Lampman, R. M. (1994). *Exercise in the clinical management of diabetes*. Champaign, IL: Human Kinetics.

Department of Health. (2004). *At least five a week: evidence on the impact of physical activity and its relationship to health. A report from the Chief Medical Officer.* London: Department of Health.

Edmunds, S. (2003). *The psychological and physiological effects of physical activity and fitness in children with Type 1 diabetes. PhD thesis*. Liverpool John Moores University, Liverpool.

Eiser, C., & Morse, R. (2001). *Quality-of-life measures in chronic diseases of childhood* (No. 5): Health Technology Assessment.

Ekeland, E., Heian, F., Hagen, K. B., Abbott, J., & Nordheim, L. (2004). Exercise to improve self-esteem in children and young people. *The Cochrane Database of Systematic Reviews*.

Fox, K. R., & Corbin, C. B. (1989). The physical self-perception profile: development and preliminary validation. *Journal of Sport and Exercise Psychology, 11*, 408-430.

Grey, M., Boland, E. A., Davidson, M., Li, J., & Tamborlane, W. V. (2000). Coping skills training for youth with diabetes mellitus has long-lasting effects of metabolic control and quality of life. *The Journal of Pediatrics, 137*, 107-113.

Grey, M., Cameron, M. E., Lipman, T. H., & Thurber, F. W. (1995). Psychosocial Status of Children With Diabetes in the First 2 Years After Diagnosis. *Diabetes Care, 18*, 1330-1336.

Grey, M., Yu, C., Boland, E. A., Sullivan Bolyai, S., Davidson, M., & Tamborlane, W. V. (1998). Short-term effects of coping skills training as adjunct to intensive therapy in adolescents. *Diabetes Care, 21*, 902-908.

Grossman, H. Y., Brink, S., & Hauser, S. T. (1987). Self-efficacy in adolescent girls and boys with insulin-dependent diabetes mellitus. *Diabetes Care, 10*, 324-329.

Hanson, C. L., De Guire, M. J., Schinkel, A. M., Kolterman, O. G., Goodman, J. P., & Buckingham, B. A. (1996). Self-care behaviors in insulin-dependent diabetes: evaluative tools and their associations with glycemic control. *Journal of Pediatric Psychology, 21*, 467-482.

Health Education Authority. (1998). *Young and active? Policy framework for young people and health-enhancing physical activity*. London: Health Education Authority.

Howells, L., Wilson, A. C., Skinner, T. C., Newton, R., Morris, A. D., & Greene, S. A. (2002). A randomized control trial of the effect of negotiated telephone support on glycaemic control in young people with Type 1 diabetes. *Diabetic Medicine, 19*, 643-648.

Ingersoll, G. M., & Marrero, D. G. (1991). A modified quality-of-life measure for youths: psychometric properties. *Diabetes Educator, 17*, 114-118.

Kokkonen, J., Taanila, A., & Kokkonen, E.R. (1997). Diabetes in adolescence: the effect of family and psychological factors on metabolic control. *Nordic Journal of Psychiatry, 51*, 165-172.

Kovacs, M., Ho, V., & Pollock, M. H. (1995). Criterion and predictive validity of the diagnosis of adjustment disorder: a prospective study of youths with new-onset insulin-dependent diabetes mellitus. *American Journal of Psychiatry, 152*, 523-528.

Landt, K. W., Campaigne, B. N., James, F. W., & Sperling, M. A. (1985). Effects of exercise training on insulin sensitivity in adolescents with type 1 diabetes. *Diabetes Care, 8*, 461-465.

Loman, D. G., & Galgani, C. A. (1996). Physical activity in adolescents with diabetes. *Diabetes Educator*, *22*, 121-125.

Munro, B. H. (1997). *Statistical methods for health care research*. Philaelphia: Lippincott.

National Diabetes Support Team (2006). Quality and Outcomes Framework Factsheet. NHS Clinical Governance Support Team.

Rossilio M., Cotton, J. B., Wieliczko, M. C., Gendrault, B., Carel, J.C., Couvaras, O., Ser, N., Gillet, P., Soskin, S., Gaeandeau, P., Stukens, C., LeLuyer, B., Jos, J., BonyTrifunovic, H., Bertrand, A. M., Leturcq, F., Lafuma, A., & Bougneres, P. F. (1998). Factors associated with glycemic control - a cross-sectional nationwide study in 2579 French chkldren with type 1 diabetes. *Diabetes Care, 21*, 1146-1153.

Sarnblad, S., Ekelund, U., & Aman, J. (2005). Physical activity and energy intake in adolescent girls with Type 1 diabetes. *Diabetic Medicine, 22*, 893-899.

Steptoe A. & Butler N. (1996). Sports participation and emotional well-being in adolescents. *Lancet*, *347*, 1789-1792.

Stewart, A. L., Hays, R. D., Wells, K. B., Rogers, W. H., Spritzer, K. L., & Greenfield, S. (1994). Long-term functioning and well-being outcomes associated with physical activity and exercise in patients with chronic conditions in the medical outcomes study. *Journal of Clinical Epidemiology, 47*, 719-730.

Stratton, G. (1996). Children's heart rates during physical education lessons: a review. *Pediatric Exercise Science*, *8*, 215-233.

Streiner, D., & Norman, G. (1995). *Health measurement scales. A practical guide to their development and use* (Second edition). Oxford, UK: Oxford University Press.

Traub, R. (1994). *Reliability for the social sciences, theory and applications*. Thousand Oaks, CA: Sage.

Treiber, F. A., Musante, L., Hartdagan, S., Davis, H., Levy, M., & Strong, W. B. (1989). Validation of a heart rate monitor with children. *Medicine and Science in Sports and Exercise, 21*, 338-342.

Trost S. G., Sallis, J.F., Pate, R.R., Freedson, P.S., Taylor, W.C. & Dowda, M. (2003). Evaluating a model of parental influence on youth physical activity. *American Journal of Preventive Medicine. 25*, 277-282.

Urquhart Law, G. (2002). Dissimilarity in adolescent and maternal representations of type 1 diabetes: exploration of relations to adolescent well-being. *Child: Care, Health and Development, 28*, 369-378.

Welk, G. J., Corbin, C. B., & Dale, D. (2000). Measurement issues in the assessment of physical activity. *Research Quarterly for Exercise and Sport, 71*, 59-73.

Welk, G. J., & Eklund, B. (2005). Validation of the children and youth physical self perceptions profile for young children. *Psychology of Sport and Exercise*, *6*, 51-65.

Whitehead, J. R. (1995). A study of children's physical self-perceptions using an adapted Physical Self-Perception Profile questionnaire. *Pediatric Exercise Science, 7*, 132-151.

Zoppini, G., Carlini, M., & Muggeo, M. (2003). Self-reported exercise and quality of life in young type 1 diabetic subjects. *Diabetes Nutrition and Metabolism, 16*, 77-80.

Table 1: Descriptive statistics for psychological questionnaires and HbA_{1c}

Variable	Range	Mean ± SD		
		Males (n=18)	**Females (n=18)**	**All (n=36)**
PSPP-C [a]				
Sport competence	1-4	2.72 ± .79	2.84 ± .59	2.78 ± .70
Condition competence	1-4	2.98 ±.52	2.79 ± .71	2.89 ± .61
Body competence	1-4	2.67 ± .72	2.18 ± .76	2.44 ± .77
Strength competence	1-4	2.82 ± .73	2.81 ± .47	2.82 ± .61
PSW	1-4	2.76 ± .64	2.51 ± .75	2.64 ± .70
GSW	1-4	3.07 ± .74	2.90 ± .85	3.00 ± .79
SED [b]				
SED-diabetes	22-132	99.68 ± 16.23	102.34 ± 16.01	101.01 ± 15.94
SED-medical	5-30	20.50 ± 5.42	21.93 ± 5.27	21.22 ± 5.31
SED-general	6-36	27.39 ± 6.91	28.67 ± 3.76	28.03 ± 5.52
DQOL-Y [c]				
Satisfaction with life	17-85	33.83 ± 13.20	34.03 ± 7.42	33.93 ± 10.55
Disease impact	22-110	49.41 ± 13.00	47.98 ± 11.40	48.70 ± 12.07
Disease related worries	0-55	15.85 ± 8.38	18.77 ± 7.44	17.31 ± 7.95
Overall health rating	1-4	3.22 ± .73	3.11 ± .58	3.17 ± .65
HbA_{1c} (%)		9.58 ± 1.74	9.77 ± 1.71	9.68 ± 1.70

[a] Items within the PSPP are scored 1-4, higher scores reflect greater perceived competence.
[b] Items within the SED are scored 1-6, higher scores reflect greater self-efficacy.
[c] Items within the satisfaction and impact subscales are scored 1-5, items within the worries subscale are scored 0-5, the overall health rating is scored 1-4. Higher scores reflect greater quality of life for the satisfaction and overall health subscales, lower scores reflect greater quality of life for the impact and worries subscales.

Table 2: Descriptive statistics for minutes of physical activity per day

Variable		**Mean ± SD**	
	Males (n =17)	**Females (n=17)**	**All (n=34)**
MVPA (minutes)	66.40 ± 34.02	47.59 ± 28.86	57.00 ± 32.50
VPA (minutes)	15.59 ± 15.37	4.03 ± 3.36	9.81 ± 12.43

Table 3: Pearson correlation coefficients (n=34)

	MVPA		**VPA**	
Variable	**r**	**p**	**r**	**p**
PSPP-C				
Sport competence	.19	.31	.12	.51
Condition competence	.38	.03	.33	.06
Body competence	.25	.17	.37	.04
Strength competence	.20	.29	.18	.32
PSW	.11	.54	.25	.16
GSW	.09	.63	.26	.15
SED				
SED-diabetes	-.17	.35	-.12	.49
SED-medical	-.17	.33	-.26	.13
SED-general	-.30	.08	-.18	.31
DQOL-Y				
Satisfaction with life	0.02	.92	.18	.32
Disease impact	-.07	.69	-.04	.84
Disease related worries	-.15	.39	-.20	.26
Overall health rating	.28	0.05*	.41	0.004*
HbA_{1c}	.02	.93	.03	.86

* Kendall’s tau-b conducted