Numeracy in Adolescents with Type 1 Diabetes: Assessment and Gaming Intervention – A Pilot Project

BY

ERENY BASSILIOUS
BScPT, University of Ottawa, 2002
MD, McMaster University, 2005

THESIS

Submitted as partial fulfillment of the requirements
for the degree of Master of Health Professions Education
in the Graduate College of the
University of Illinois at Chicago, 2013

Chicago, Illinois

Defense Committee:

Carol Kamin, Chair and Advisor
Alan Schwartz
Farid Mahmud, University of Toronto
Adam Dubrowski, University of Toronto

TABLE OF CONTENTS

TABLE OF CONTENTS (continued)

LIST OF TABLES

LIST OF FIGURES

SUMMARY

Numeracy is the ability to understand and use numbers in daily life and is central to diabetes self-management. In this pilot project I examined the relationship between diabetes numeracy, A1C (a measure of blood sugar control), and quality of life in an ethnically diverse population of adolescents with type 1 diabetes and then applied a novel video game intervention geared at improving diabetes numeracy.

Through collaboration with diabetes team members and adolescents at our instituion, as well as experts in technology development and education research, we created a video game de novo addressing diabetes numeracy. I assessed diabetes numeracy using the adolescent diabetes numeracy test (aDNT14) and correlated this with cumulative A1C, quality of life, and demographic data in 42 adolescents. After playing the video game on three separate occasions I re-evaluated participants' diabetes numeracy (n=33). To test retention of the video game effects I re-evaluated baseline measures within 1 month following the last video game session and cumulative A1C over the following 6 months.

There is a significant association between baseline A1C and numeracy scores ($r=-0.43$, $p= 0.004$) independent of ethnicity. Although improvement in numeracy skills after the video game intervention did not reach statistical significance, some domains of quality of life measures significantly improved. In secondary exploratory analysis, reading literacy was highly associated with diabetes numeracy skills ($p<0.001$). In addition, stronger numeracy skills were associated with more intense insulin regimens (insulin pump) ($p=0.0272$). Finally, baseline diabetes related quality of life was inversely associated with the number of times per week the patient reported to have forgotten to take insulin ($p = 0.0009$).

Numeracy skills are strongly correlated with diabetes control and is a skill set that is not dependent on ethnicity or socio-economic status. Some limitations to the study, in particular the controlled administration of the video game, may have limited the intervention effect of the video game on the primary outcome measures. However, video games are an interactive and developmentally appropriate method of delivering experiential learning to adolescents and should be explored further as a means of delivering diabetes education to adolescents with type 1 diabetes.

I. INTRODUCTION

A. Background

Type 1 diabetes is one of the most common chronic diseases in children and adolescents[1]. Patients with type 1 diabetes need to enagage in multiple diabetes related calculations every day. Numeracy, the ability to understand and apply numbers to daily life [2], directly affects their ability to self manage their diabetes [3]. Furthermore, low numeracy is prevalent (55% of Canadians have low numeracy skills) [4] and low numeracy has been implicated in poorer managment of multiple chronic health conditions such as asthma and obesity [5] [6] [7]. In adults with diabetes, both low health literacy and low numeracy were associated with poor clinical outcomes [2]. The current generation of children and adolescents are exposed to very different teaching methodolgies which are heavily influenced by technology. Additionally, in our setting, children and adolescents have been shown to have equivalent access to diabetes care [8]. Therefore, the association between literacy, numeracy and clinical outcomes which was demonstrated in the adults studies may not be as generalizable to a younger population.

Adolescents also represent a population at special risk. Adolescence is frequently a time of deteriorating blood glucose control, partly due to growth and puberty [9] [10], psychosocial variables [11], the complexity of the intense treatment regimens [12], and a mismatch between the health team's expectations and the capabilities of the adolescent patient. The demands of diabetes management on the personal time, efforts, and emotions are a great burden on any patient with type 1 diabetes and particularly on adolescents with type 1 diabetes[13]. Interestingly, self reported diabetes related quality of life is not associated with measures of glycemic control [14] leaving a question as to whether other factors, such as comfort with health literacy or numeracy skills, can be associated with the quality of life of patients with diabetes.

Finally, the current generation of adolescents embrace technology and prefer learning through experiential learning methods [15] [16]. Previously described technology interventions aimed at improving numeracy have only been mainly applied to adults. These interventions have been relatively simple and "low tech" and most have failed to show a sustained effect after the intervention was discontinued [17] [18]. As well, most of these interventions relied on factors external to the patient, using reminders and counseling from health team members. This is in contrast to the use of gaming technology, that is patient centered and patient driven. Video games in particular are an excellent medium for experiential learning as they provide the participant with concrete experiences and opportunity for active experimentation [19] [20]. Video game technology have been successfully implemented in health professional education [21] [22] [23]. However, there have been limited studies to date exploring the role of developmentally appropriate technology, such as video games, for improving numeracy skills in adolescents.

B. Statement of the Problem

Until recently, the relationship between numeracy and glycemic control in adolescents had not been explored. Mulvaney et al recently demostrated, in an unpublished study, an association between numeracy and glycemic control (A1C) in relatively ethnicially homogenous group (90% were white) of adolescents with type 1 diabetes[24]. However, data is lacking on the relationship between numeracy and glycemic control as well as the relationship between numeracy and quality of life, in ethnically diverse adolescents. Furthermore, there are limited studies examining the effect of a developmentally appropriate educational intervention to improve diabetes specific numeracy skills.

C. Purpose of the Study

The first objective of this study is to assess the association between baseline diabetes-related numeracy with glycemic control (A1C) and quality of life (QL) in adolescents with type 1

diabetes in an urban ethnically diverse population. We hypothesize that participants with low diabetes numeracy test scores at baseline will have higher A1C measurements and lower QL as compared to participants with higher diabetes numeracy test scores. The second objective is to apply an interactive video game interventation aimed at improving diabetes-related numeracy and examining its effects on the outcome measures of diabetes related numeracy, A1C, and QL. We hypothesize that through participating in the video game intervention, participants with mid range numeracy scores will experience an improvment in their numeracy test scores in addition to improvement in QL immediately post intervention, and A1C both immediately and 6 months after the video game intervention. We expect that the game would be most benefitical for participants with mid range baseline numeracy scores and therefore designed the game to target this group of participants. Those with scores in the lowest tertile may represent undiagnosed learning difficulties and thereby may not benefit from the video game intervention. Similarly, participants with the scores in the highest tertile will likely not show improvement in numeracy skills after the intervention (ceiling effect).

II. METHODS

A. Setting and Study Participants

From May 2011 to July 2011 we enrolled 44 study participants from the type 1 diabetes clinic at the Hospital for Sick children (SickKids), a tertiary care hospital in Toronto, Canada. Study participants were 13 to 18 years old, were diagnosed with type 1 diabetes for at least 1 year (based on Canadian Diabetes Association criteria), and had their initial diabetes education at the Hospital for Sick Children diabetes clinic. They were excluded from the study if they had poor proficiency of the English language, had a known learning disability or psychiatric/behavioral diagnosis, or had a visual or hearing impairment. Participants received high-school volunteer hours and a total of $45 iTunes gift cards given incrementally during the multiple study visits. In addition, their bus fare for transportation to and from the study visits was also provided. This study was approved by the REB at the Hospital for Sick Children and the IRB at the University of Illinois at Chicago. We obtained written consent from all participants and one parent in attendance.

B. Data and Procedures

1. Data gathering for game content and design:

We conducted meetings with an advisory group composed of diabetes team members at our instituion, including diabetes nurse educators, dieticians, social workers, child life specialists, and physicians, to determine the most essential domains of diabetes numeracy to address in the video game design. In these meetings we used Q sort methodology [25] to reach a consensus on the most important content to teach in the game. We presented the advisory group members with 12 predetermined diabetes numeracy skills (chosen through consensus by the authors and experts in diabetes) who with a preselected number of post-it notes ranked the topics they felt were most important to address in the game. As a group these choices were further discussed until

consensus on the top 5 most important topics in diabetes numeracy was reached. These five essential diabetes numeracy topics indentified included: blood glucose (BG) interpretation; carbohydrate counting; insulin dose calculation for meals; calculation of correction insulin; BG and exercise. Input from adolescents added features to enhance interactivity and stimulation. Using these data, in colloaboration with experts in technology development and education research, we created a video game de novo addressing diabetes related numeracy in which was embedded the instruction of these five essential diabetes managment skills. This video game, named “Power Defense”, is based on the tower defense genre of video games (Figures 1, 2, and 3). Prior to starting the recruitement process for the study, we “alpha” tested the game on 8 adolescent volunteers from the diabetes clinic waiting room. Their feedback helped us enhance the graphics, music, an asthetic appeal of the video game. As well, we used the adolescents’ feedback for addressing technical glitches, such as slow or ineffective transitions between levels.

2. Description of the game:

In *Power Defense*, the player is responsible for balancing the amount of energy allowed into a reactor-based power base station (represents the person with Type 1 Diabetes) which stores energy (represents “blood sugar level”) (Figure 1). Players can place towers which drain energy (represents exercise), and can use “real-time coolant” (represents short acting insulin), and “daily super coolant” (represents long acting insulin) to maintain the desired energy level (represents daily blood sugar levels). Calculations for the amount of coolant to inject or the amount of “energy” to let in must be performed in real time, similar to calculations performed by patients with diabetes for managing their blood sugar levels. During

an “attack wave”, energy entities (represents food) try to reach the base station. The goal is for the player to survive as many waves of energy attacks as possible, while keeping base station’s power output level within the acceptable range. The challenge is to let enough energy make it to the base while not letting in an excessive amount which would lead to power overload. When the power level falls below a pre-set threshold, the game screen starts to blur (mimicking symptoms of low blood sugar) (Figure 2). When the power output is too high, the player is prompted to inject coolant.

Implicit teaching strategies are employed for the acquisition of diabetes numeracy skills through *Power Defense*. To enhance transfer of knowledge and skills to real life diabetes management [26] we also incorporated explicit strategies of teaching; at certain points in the game, depending on specific user actions, the player is presented with diabetes-specific questions (Figure 3) which if answered correctly, are awarded accordingly. If they answer incorrectly, they are provided with the correct answer and an appropriate explanation.

The game also tracks various player statistics including: number of correct or incorrect calculations, time spent within and outside of optimal power range, number of questions answered correctly.

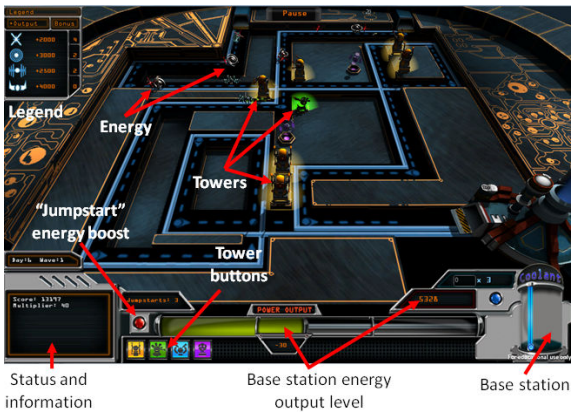

Figure 1. Game-play screenshot

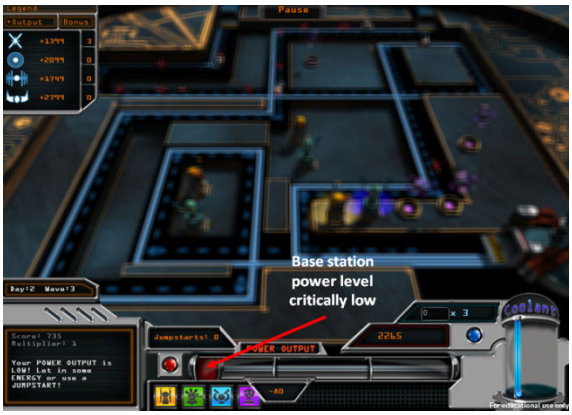

Figure 2. Blurring effect screenshot

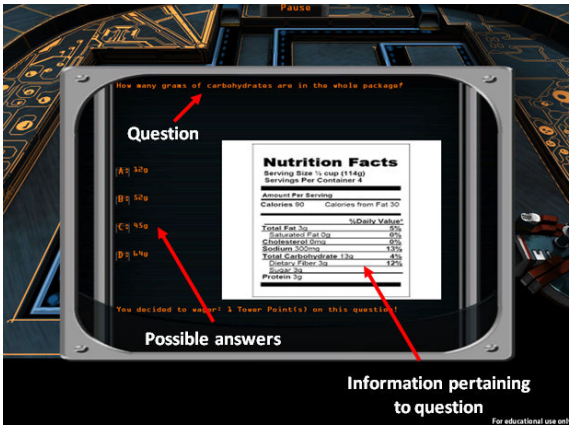

Figure 3. Sample question screenshot

3. Recruitment and administration of gaming intervention

Recruitment, administration of consent process, collection of all data and administration of the video game intervention was all performed by a single person (author EB), thereby standardizing the process and minimizing any potential additional confounding variables. EB recruited potential participants from the waiting room during type 1 diabetes clinics, obtained written consent, and gathered data including glycemic control (A1C) and demographic information about the participant and one parent in attendance, confirmed by chart review. EB then administered tests of literacy, general numeracy, diabetes-related numeracy, general and diabetes specific quality of life, and diabetes related problem solving skills. Demographic and clinical self-reported information included patient and parent age, sex, patient and parent education level, proficiency of math skills at school, video game playing habits, ethnicity, and annual household income. Through examination of the electronic medical records, EB collected A1C measurements and calculated an average (arithmetic mean) A1C level for the 6 months prior to enrollment.

The adolescents participated in 3 video game sessions during which they played the video game for 1 hour in a designated research room at the study centre. They attended 3 sessions within 1 week separated by at least 1 day between each session. After completion of the third video game session, diabetes numeracy was reassessed using a modified version of the aDNT-14. A month after this session, participants returned to play the game a final time. At this visit, measures of diabetes numeracy, literacy, general numeracy, quality of life, and problem solving were reassessed, in order to help ascertain if the video game intervention successfully improved diabetes numeracy skills as opposed to

improvement in the other domains of general numeracy, literacy and problem solving. Similarly, the re-administration of these measures would help explain the reason for the effect on glycemic control if any. Finally, A1C measurements were collected and an average (arithmetic mean) A1C level for the 6 months after completion of the video game intervention was calculated in order to examine the study's sustained effect on diabetes control.

C. Measurement Tools

Diabetes related numeracy. Diabetes related numeracy skills were assessed using recently validated adolescent Diabetes Numeracy Test (aDNT-14)[24]. The shortened 14 item version was administered during this study. The advantage of the aDNT-14 is that it assesses numeracy skills specifically related to diabetes self care. Participants were provided with a basic function calculator and no time limit was imposed for completion of the aDNT-14.

General numeracy. General numeracy was assessed using the wide-range achievement test, fourth edition, math section. The WRAT-4 is a widely validated test that measures general calculation skills [27].

Literacy. Literacy was assessed using the Rapid Estimate of Adolescent Literacy in Medicine (REALM-teen), a validated word recognition test used as a screening tool for literacy and is a good predictor of general reading ability in English [28].

Quality of life (QL). General and diabetes specific quality of life was assessed using the PedsQL 3.0 inventory. The generic core scale and the diabetes specific module were administered to both parent and child. This tool is valid and reliable for adolescents with type 1 diabetes as well as their caregiver(s) [29].

Glycemic control (A1C). Glycemic control was assessed by calculating an arithmetic mean A1C for each patient during the 6 months prior to enrollment in the study and the 6

months following completion of the study. An average A1C was chosen in contrast to the most recent single A1C in order to provide a better reflection of actual patient glycemic control trend. The A1C data was obtained from participants' medical records.

Average time for completion of all measure was 75 minutes.

D. Analyses

Statistical analysis was performed using SAS version 9.3. Sample size of 42 participants was calculated based on unpublished data from Vanderbilt centre validation of the aDNT-14 measure [24]. Although our population is not similar to Vanderbilt's centre (our population is more ethnically heterogeneous), theirs is the only study validating the aDNT-14 which is the only tool currently available for assessing numeracy skills in adolescents. We therefore used their mean scores as the baseline to calculate the required sample size, using an alpha of 0.05, power of 80%, in a 1 sided sample size calculation. To detect a 10% improvement, we needed a minimum of 32 participants. Assuming a 30% drop out rate we recruited 42 participants for the study.

Descriptive statistics mean and standard deviation for continuous variables and percentages for categorical variables were calculated to describe the sample. For secondary data analysis we used two sample T test and analysis of variance to assess associations between continuous and categorical variables; Pearson correlation to assess association between two continuous variables; Chi-squared test to assess association between two categorical variables. The paired T test was used to assess the change from the baseline for continuous measurements. All tests are two sided and $p<0.05$ is considered statistically significant.

The relationship between numeracy skills and measures of diabetes control (A1C and QL) were described using Spearman correlation coefficients between aDNT-14and A1C at baseline and between aDNT-14and QL at baseline. We characterized participants based on tertiles of aDNT-14scores (0-25%, 26-74%, 75-100%). We then used analysis of variance to compare mean A1C across aDNT-14score tertiles. This was to explore whether these variables are associated in a U-shaped association. Using Spearman's correlation coefficient we examined the relationship between numeracy scores at baseline and QL at baseline. We then used two sample T-test to compare mean A1C and mean QL between participants with low numeracy and participants with high numeracy (across tertiles of aDNT-14scores).

To examine the effect of the video game intervention on numeracy, A1C and QL, we used within subject paired t-tests to compare pre- and immediately post- levels of aDNT-14. We then used the same tests to compare pre- and delayed-post levels of the aDNT-14, A1C and QL.

III. RESULTS

A. Participant Characteristics

From May 2011 to July 2011, forty two patients who met eligibility enrollment criteria were recruited from the type 1 diabetes clinic waiting room at the Hospital for Sick Children, Toronto, Canada. Of these, 33 (79%) participants completed the study. Of the 9 participants who did not complete the study, eight did not present to the first video game session, despite voicing interest and multiple telephone reminders, and one patient did not present to the final video game session due to conflicting time commitments with starting college. Characteristics of the 42 participants recruited and the 33 participants who completed the study are presented in Table 1.

TABLE I

PARTICIPANT CHARACTERISTICS

Characteristic	Participants completed study n=33	Participants not completed study n=9	P value
Mean age (years)	16.8	16.9	0.9072
Male (%)	51.50%	55.70%	0.8297
Born in Canada (%)	90.90%	77.80%	0.2808
Mean years of diabetes diagnosis	7.8 years	8.7 years	0.5998
Average A1C at baseline (%)	8.3	8.7	0.6
Average aDNT-14scores at baseline	10.4	10.1	0.8311
% who completed math level ≤ grade 9 (%)	19/33 (57.6%)	5/9 (55.6%)	0.9136
Average math mark (%)	72.7	78.8	0.2433
% who monitor blood glucose ≤ 2 times/day	3/33 (9.1%)	2/7 (22.2%)	0.2809
% on insulin pump	19/33 (57.6%)	2/9 (22.2%)	0.13
% MDI insulin regimen (≥4 times/day)	8/14 (57.1%)	1/7 (14.3%)	0.1588
% TID insulin regimen (3 times/day)	6/14 (42.9%)	6/7 (85.7%)	0.1588
Average global QL score (0-100)	78.10	76.50	0.73
Average diabetes QL score (0-100)	72.20	71.70	0.93
Average REALMteen score (0-66)	61.80	61.10	0.75
% with parental education ≤ high school	7/33 (21.2%)	4/9 (44.4%)	0.2086
% with total household income ≤ $50,000/year	7/33 (21.2%)	3/9 (33.3%)	0.6603

B. Primary Analysis

1. Diabetes related numeracy and glycemic control

We hypothesized that participants with low numeracy test scores at baseline will have higher A1C measurements as compared to participants with higher diabetes numeracy test scores. The Spearman correlations shows significant association between baseline A1C and baseline numeracy test results (Rho= -0.43, p=0.0041) (Figure 4). This relationship still holds true when comparing A1C among 3 numeracy tertile groups using analysis of variance. There is clearly a significant gradient; as numeracy test results increase then A1C decreases (p=0.0151). Unpaired T-test showed no association between aDNT-14results and ethnicity (white vs. Non-white) p=0.3.

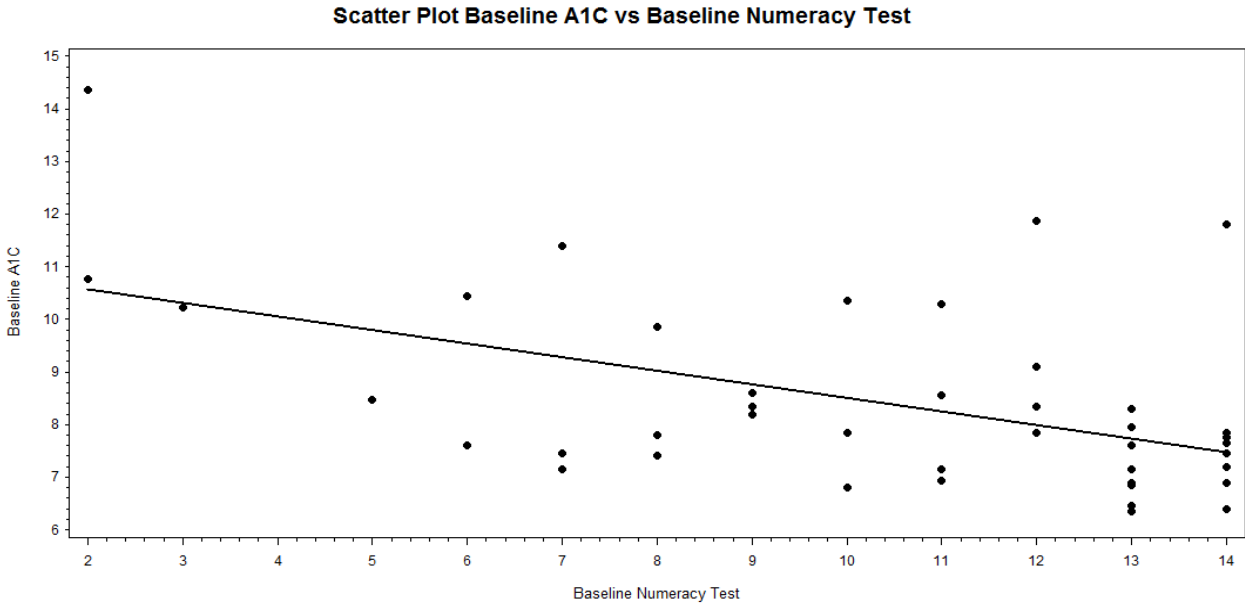

Figure 4. Relationship between baseline A1C and baseline numeracy test scores

The solid line is the best fitted line associating Diabetes Numeracy Test score and hemoglobin A1C

2. Diabetes related numeracy and quality of life

We hypothesized that participants with low numeracy test scores at baseline will have lower general and diabetes related quality of life as compared to participants with higher diabetes numeracy test scores. Using two sample t-test, there was no significant difference in either global scores or sub-domain scores in the both general and diabetes quality of life when comparing those with lower or higher numeracy (lowest 2 aDNT-14 score tertiles and highest aDNT-14 score tertile) (p= 0.2442 and p=0.8054 respectively).

3. Intervention effect on diabetes related numeracy, A1C, and QL

There was no significant intervention effect on diabetes related numeracy as evidenced by stable aDNT-14 mean scores pre-intervention (10.3, SD 3.5), immediately post intervention (10.7, SD 3.1), and 1 month following the intervention (10.5, SD 3.2). There was also no significant effect of the video game intervention on A1C, global QL, or diabetes QL (table below).

TABLE II

INTERVENTION EFFECT ON A1C AND QUALITY OF LIFE SCORES

	Pre-intervention mean (sd)	**Post-intervention mean (sd)**
A1C	8.3 (1.7)	8.4 (1.4)
Global QL scores	77.8 (12)	79.9 (14.9)
Diabetes QL cores	72.1 (16.5)	74.8 (15.4)

C. Secondary Analysis

We included all 42 participants enrolled to explore associations with baseline characteristics and outcomes. We used Spearman's correlation coefficient to examine the association of aDNT-14, REALMteen, DPMSA, WRAT-4) with A1C at baseline, and we used ANOVA to examine which demographic features are associated with A1C at baseline. Only parental education was associated with baseline A1C. As parental education increased above high school level, baseline A1C measures decreased (p=0.03). For demographic features only math grade at school was significantly associated with baseline numeracy. As the participants' math marks increased so did their baseline numeracy test scores (Rho= 0.43, p=0.004). There is also a significant association between literacy (REALMteen) and numeracy at baseline (p<.001) as well as literacy and A1C at baseline (p=0.03).

Interestingly, in an exploratory ANOVA analysis, we found a significant difference between mean baseline aDNT-14 scores between participants on insulin pump, MDI regimen, and TID regimens (11.476, 10.25, 8.167, p=0.0272). The means between baseline numeracy scores of participants on insulin pump compared with those on TID regimens are statistically different however the mean difference in numeracy scores of those on a pump compared with those on MDI regimen and those on MDI regimen compared with those on TID regimens are not statistically significant. The same findings were true of baseline A1C measures between these 3 subgroups of Pump, MDI, TID insulin regimens (7.888, 8.363, 9.462, p= 0.046).

As well, baseline diabetes related quality of life was inversely associated with the number of time per week the patient forgets to take insulin (p = 0.0009).

IV. DISCUSSION

Our study aimed to firstly assess baseline association between numeracy, A1C and Quality of life of adolescents with type 1 diabetes and then to explore the impact of a de novo video game intervention on these outcome measures.

A. Primary Outcomes

This study demonstrates that in adolescents with Type 1 Diabetes, low numeracy and literacy is significantly associated with worse glycemic control. This association was previously demonstrated only modestly in adults with mainly type 2 diabetes [2] and an ethnically relatively homogenous population of adolescents with type 1 diabetes[24]. Forty five percent of participants in our study were non-white, which is highly representative of our urban ethnically diverse clinic population [30]. Whereas in adults with diabetes, ethnicity (African American) was also found to be associated with lower glycemic control, this was not true in our study population. This may be due to improved equality of access to education and health care for children and adolescents, regardless of ethnicity or socioeconomic status [8]as compared with the older adult population previously studied.

No effect of diabetes numeracy on QL was found in this study. However, quality of life is complex and multi-factorial and likely not explained by numeracy alone. Life circumstances, such as developmentally appropriate adolescent challenges as well as the burden of a chronic illness, likely heavily influence QL.

Interestingly, the developmentally appropriate and interactive video game intervention did not produce a change in diabetes numeracy, A1C or QL. It is therefore likely that the duration of the study and the “dose” (length of time played) as well as the frequency of the video game intervention were insufficiently short to effect a significant change in these complex and

multi-factorial outcome measures. Furthermore, as this is the first study of its kind, the application of the video game intervention was quite controlled in terms of location, time played, and frequency. This is contrary to the nature of video games in which the player engages with the video game at the time and location of his/her choice and is played as frequently as desired. Video games embody experiential learning and therefore are best applied as determined by the learner's need. The controlled application of the video game in our study may have therefore hindered the effects of the video game on numeracy and thereby on A1C and QL.

B. Secondary Outcomes

The significant association between literacy (REALMteen) and numeracy at baseline as well as literacy and A1C at baseline is interesting. In our study, participants with high numeracy tended to also score high in literacy scores, and vice versa. This is in contrast to finding from adult studies. Many adult patients have adequate literacy skills but poor numeracy skills. In a study assessing adult patient understanding of food labels, 77% of patients had at least grade 9 literacy skills but only 37% of these patients had numeracy skills at a grade 9 level [7]. In a cross-sectional study of 3260 Medicare adult patients with and without diabetes, 23% of patients with adequate literacy skills could not conclude whether a blood glucose value was in target range [31]. The development of literacy and numeracy skills in children is quite complex and multi-factorial. Literacy and numeracy may be related to parental skills, socioeconomic status, nutritional status, and physical activity levels. [32] In addition, literacy skills develop in a different trajectory than numeracy skills. Literacy seems to develop in a sequential manner, after decoding is mastered then there is quantitative acquisition of vocabulary and grammar as well as improved comprehension. Numeracy however tends to involve new conceptual categories which are built on basic numerical knowledge but are also distinctive categories on their own. Therefore excellence in one domain (i.e. geometry) does not always predict excellence in a different domain (i.e. calculus) [33]. Research is lacking on how and when numeracy and

literacy skills are codependent and the timing of when this codependence ceases. The finding in our study may indicate that numeracy skill acquisition is still quite dependent on literacy skills, even in the adolescent years. This warrants further investigation as the prevention of poor numeracy skills later in life may require intervention at earlier developmental stages.

Additionally, it is important note the association between baseline A1C and numeracy scores and the type of insulin regimen the participant has. Participants on the most complex insulin regimen (insulin pump) had significantly higher numeracy scores and significantly lower A1C measures as compared to participants on the simplest (TID) insulin regimen. This association may indicate that patients with strong numeracy skills at baseline are more likely to have success on insulin pump therapy as evidenced by lower A1C measures. This association could also reflect a selection bias by the diabetes team who may intuitively chose to initiate insulin pump therapy in motivated patients with high numeracy scores and lower A1C measures. It would be important to further examine this association to help direct the assessment of numeracy skills in patients before selecting the insulin regimen in order to improve success rates on the regimen chosen.

Diabetes related quality of life was inversely associated with the number of time per week the patient forgets to take insulin. This could indicate that patients with lower diabetes quality of life are less likely to engage in diabetes self management and are more likely to forget to take their insulin therapy. On the flip side, this association could indicate that omitting insulin therapy (or engaging less in disease self management) could lead to lower diabetes related quality of life. Regardless of the direction of the association, video games again can be a media for engaging adolescents and promoting disease self management.

C. Application to Practice

Several findings from this study are useful for the multi-disciplinary team involved in the care of adolescent patients with type 1 diabetes. Firstly, given the strong association between numeracy and glycemic control, it is imperative that health care team members are aware of the patient's numeracy skills before tailoring educational strategies to their needs. Secondly, diabetes numeracy and literacy can and should be assessed at diagnosis to help guide the choice of insulin therapy regimen and before making major changes to the patient's diabetes regimen, such as initiating more complex insulin pump therapy. Furthermore, the method for delivering education of numeracy skills to adolescents needs to be engaging, interactive, and developmentally appropriate. In addition, secondary findings from the study hint towards the importance of strong literacy skills in association with numeracy. Therefore literacy, in particular health literacy, may be also worthwhile assessing before tailoring the patient`s treatment regimen and educational strategies to their appropriate literacy level. Finally, we found that adolescents who are more engaged in their diabetes self management, evidenced by less insulin omission, tended to have a higher perceived quality of life. Working on strategies to engage adolescents with type 1 diabetes should be one of the team`s main and ongoing objectives.

D. Study Limitations

There are several limitations to our study. Firstly, as this is the first study of its kind to assess numeracy skills in adolescents with type 1 diabetes and to apply a novel video game intervention, it was therefore primarily a pilot study. Therefore, participant numbers were low, thereby limiting the number of statistical power that could be applied. In addition, the first part of the study assessing baseline diabetes numeracy skills in relation to glycemic control and quality of life is cross sectional in nature and therefore the results reported are informative but can only describe associations. Secondly, because it was a pilot study, the location, time and timing of the video game intervention was limited and controlled, which is against the nature of user

initiated play with video games. This may have in turn limited the intervention effect of the video game. Thirdly, the aDNT-14tool used in this study is the only validated measure of diabetes numeracy in adolescents and has some limitations. The questions in this tool are quite basic and may not sufficiently challenge adolescents who are faced with calculation challenges multiple times per day. It may therefore not be sensitive or specific enough to reflect small changes in numeracy skills. We administered the aDNT-14at baseline and then modified it by changing the order of the questions and changing the values within the questions in order to re-administer it immediately after the third video game visit and 1 month after the intervention. There would be a concern for testing effect (learning from repeated taking of the test), however this was not evident as in fact aDNT-14scores were stable with repeated testing. Fourthly, the patients who enrolled in our study were motivated adolescents who generally had good numeracy skills and good A1C measures (mean 8.3) compared with the clinic mean (mean 8.6). Therefore, the video game intervention may not be able to improve their skills further; in essence this is a ceiling effect. Fifth, this study excluded non-English speaking patients, who may be immigrants and at higher risk for lower numeracy and worse glycemic control. Finally, in this study we did not assess parental numeracy skills which may be important if parents are still involved in their adolescent's diabetes management. However, we opted not to measure parental numeracy as it was time consuming and added to the battery of questionnaires at baseline.

V. CONCLUSIONS

A. Summary and Contributions

Low diabetes related numeracy is associated with worse glycemic control. Diabetes related numeracy is a patient characteristic that can and should be assessed at diagnosis and at critical time intervals during insulin management, particularly if one is considering transitioning an adolescent with type 1 diabetes to insulin pump therapy. Assessing diabetes related numeracy and making the team aware of the patient's numeracy level can help team members tailor their educational strategies. Video games are a developmentally appealing media for education as it engages the adolescent in experiential learning. Our study's limitations, mentioned above, may have impacted the evidence for success of a video game intervention designed to improve diabetes numeracy. Despite this however, video games and other interactive technologies should be further studied as numeracy- focused intervention for young patients with diabetes.

B. Future Directions

A few interesting findings from secondary analyses are worth future exploration. Firstly, further studies are needed to explore the developmental sequence of literacy and numeracy skills in young children with particular attention to the convergence of the interdependence between these 2 domains. This will in turn help direct numeracy and literacy interventions at the appropriate developmental age group. Secondly, further exploration of the association insulin pump therapy and numeracy skills as well as other predictive factors for lower A1C, would help clinicians individualize their decision of insulin therapy regimens that would have the highest chances at successfully lowering A1C measures. Thirdly, it would be worthwhile exploring the direction of the association between forgetting to take insulin and lower quality of life as an intervention geared at one of these factors may influence the other. Finally, it is important to develop a more sensitive tool for assessing numeracy skills. This would enable the health care

team to accurately gauge patients' numeracy skills and capture small but clinically important changes in numeracy.

Specifically related to primary outcomes in our study, future studies are needed to examine the impact of gaming interventions specifically for patients with low numeracy, with a larger study population and with longer more flexible exposure to the technology intervention.

CITED LITERATURE

1. CDA, *2008 Clinical Practice Guidelines for the Prevention and Management of Diabetes in Canada.* Canadian Journal of Diabetes, 2008. **32**(suppl 1): p. s150-162.

2. Osborn, C.Y., et al., *Diabetes numeracy: an overlooked factor in understanding racial disparities in glycemic control.* Diabetes Care, 2009. **32**(9): p. 1614-9.

3. Cavanaugh, K., et al., *Association of numeracy and diabetes control.* Ann Intern Med, 2008. **148**(10): p. 737-46.

4. Statistics Canada, *Building on our Competencies: Canadian Results of the International Adult Literacy and Skills Survey 2003*, U.N.C.f.E.S. Human Resources and Skills Development Canada, Organisation for Economic Co-operation and development, Editor. 2005.

5. Apter, A.J., et al., *Asthma numeracy skill and health literacy.* J Asthma, 2006. **43**(9): p. 705-10.

6. Huizinga, M.M., et al., *Low numeracy skills are associated with higher BMI.* Obesity (Silver Spring), 2008. **16**(8): p. 1966-8.

7. Rothman, R.L., et al., *Patient understanding of food labels: the role of literacy and numeracy.* Am J Prev Med, 2006. **31**(5): p. 391-8.

8. Zuijdwijk, C.S., M. Cuerden, and F.H. Mahmud, *Social determinants of health on glycemic control in pediatric type 1 diabetes.* J Pediatr, 2013. **162**(4): p. 730-5.

9. Amiel, S.A., et al., *Impaired insulin action in puberty. A contributing factor to poor glycemic control in adolescents with diabetes.* N Engl J Med, 1986. **315**(4): p. 215-9.

10. Moreland, E.C., et al., *The impact of physiological, therapeutic and psychosocial variables on glycemic control in youth with type 1 diabetesmellitus.* J Pediatr Endocrinol Metab, 2004. **17**(11): p. 1533-44.

11. Helgeson, V.S., et al., *Brief report: trajectories of glycemic control over early to middle adolescence.* J Pediatr Psychol, 2010. **35**(10): p. 1161-7.

12. Mortensen, H.B., et al., *Insulin management and metabolic control of type 1 diabetesmellitus in childhood and adolescence in 18 countries. Hvidore Study Group on Childhood Diabetes.* Diabet Med, 1998. **15**(9): p. 752-9.

13. Delamater, A.M., *Quality of Life in Youths with Diabetes.* Diabetes Spectrum, 2000. **13**: p. 42-46.

14. Grey, M., et al., *Personal and family factors associated with quality of life in adolescents with diabetes.* Diabetes Care, 1998. **21**(6): p. 909-14.

15. Mangold, K., *Educating a new generation: teaching baby boomer faculty about millennial students.* Nurse Educ, 2007. **32**(1): p. 21-3.

CITED LITERATURE (continued)

16. Sinclair, B. and K. Ferguson, *Integrating simulated teaching/learning strategies in undergraduate nursing education.* Int J Nurs Educ Scholarsh, 2009. **6**: p. Article7.

17. Cooper, H., J. Cooper, and B. Milton, *Technology-based approaches to patient education for young people living with diabetes: a systematic literature review.* Pediatr Diabetes, 2009. **10**(7): p. 474-83.

18. Kumar, V.S., et al., *The DAILY (Daily Automated Intensive Log for Youth) trial: a wireless, portable system to improve adherence and glycemic control in youth with diabetes.* Diabetes Technol Ther, 2004. **6**(4): p. 445-53.

19. Kolb, D., *Experiential learning: experience as the source of learning and development.* 1984, Englewood Cliffs, New Jersey: Prentice-Hall.

20. Cowen, K.J. and A.S. Tesh, *Effects of gaming on nursing students' knowledge of pediatric cardiovascular dysfunction.* J Nurs Educ, 2002. **41**(11): p. 507-9.

21. Gofton, W., et al., *The effect of computer navigation on trainee learning of surgical skills.* J Bone Joint Surg Am, 2007. **89**(12): p. 2819-27.

22. Gamberini, L., et al., *Designing a serious game for young users: the case of happy farm.* Stud Health Technol Inform, 2009. **144**: p. 77-81.

23. Mayo, M.J., *Video games: a route to large-scale STEM education?* Science, 2009. **323**(5910): p. 79-82.

24. Mulvaney SA, L.J., Cavanaugh K, Rothman RL *Validation of the diabetes numeracy test with adolescents.* Journal of Health Communication, 2013 (in press).

25. Webler, T., S. Danielson, and S. Tuler (2009) *Using Q method to reveal social perspectives in environmental research*.

26. Sun, R., P. Slusarz, and C. Terry, *The interaction of the explicit and the implicit in skill learning: a dual-process approach.* Psychol Rev, 2005. **112**(1): p. 159-92.

27. Reynolds, C. and R. Kamphaus, *Handbook of psychological and educational assessment of chidren - Intelligence, aptitude and achievement. 2nd Edition*. 2003, New York: The Guildford press.

28. Davis, T.C., et al., *Development and validation of the Rapid Estimate of Adolescent Literacy in Medicine (REALM-Teen): a tool to screen adolescents for below-grade reading in health care settings.* Pediatrics, 2006. **118**(6): p. e1707-14.

29. Varni, J.W., et al., *The PedsQL in type 1 and type 2 diabetes: reliability and validity of the Pediatric Quality of Life Inventory Generic Core Scales and type 1 diabetesModule.* Diabetes Care, 2003. **26**(3): p. 631-7.

CITED LITERATURE (continued)

30. Yeshayahu, Y., et al., *Type 1 diabetesas a Risk Factor for Impaired Vitamin D Status in a Multi-Ethnic Cohort of Canadian Adolescents.* Canadian Journal of Diabetes, 2012. **36**(6): p. 314-319.

31. Gazmararian, J.A., et al., *Health literacy among Medicare enrollees in a managed care organization.* JAMA, 1999. **281**(6): p. 545-51.

32. O'Dea, J.A. and A.C. Mugridge, *Nutritional quality of breakfast and physical activity independently predict the literacy and numeracy scores of children after adjusting for socioeconomic status.* Health Educ Res, 2012. **27**(6): p. 975-85.

33. LeFevre, J.A., *Research on the development of academic skills: introduction to the special issue on early literacy and early numeracy.* Can J Exp Psychol, 2000. **54**(2): p. 57-64.

VITA

NAME:	Ereny Bassilious
EDUCATION:	BSc.PT (physiotherapy), University of Ottawa, Ottawa, Canada, 2002 MD, McMaster University, Hamilton, Canada, 2005 MHPE, University of Illinois at Chicago, Chicago, Illinois, 2013
TEACHING	School of Medicine, University of Toronto EXPERIENCE: Arts and Science of Clinical Medicine (ASCM), Medical Student Tutor, 2007-2010 Metabolism and Nutrition Week, Adrenal Seminar leader, 2010-2011 Department of Pediatrics, Division of Endocrinology, McMaster University EXPERIENCE: Hospital Wide Grand rounds, 2012
HONORS:	Canadian Pediatric Endocrine Group research fellowship, 2010
PROFESSIONAL MEMBERSHIP	Royal College of Physicians and Surgeons of Canada Ontario Medical Association Canadian Pediatric Endocrine Group International Society for Adolescent and Pediatric Diabetes
ABSTRACTS:	M Batthish, E Bassilious, N Blanchette, G Soon, N Luca, R StBernard, T Cameron, T Bahr, AHyman, G Tait, B Feldman, R Schneider, S Tse: The Development of an Interactive Web-Based Rheumatology Teaching Module. ACR Annual Meeting, Philadelphia. Arthritis and Rheumatism 2009: 60 (10S):pp S508 E. Bassilious, A. DeChamplain, I. McCabe, M. Stephan, B. Kapralos, F. Mahmud, and A. Dubrowski. Power defense: A video game for improving diabetes numeracy. In Proceedings of the Third IEEE International Games Innovation Conference, City of Orange, CA, USA, November 2-4, 2011 E. Bassilious, Numeracy in Adolescents with Type 1 diabetes– development of an innovative gaming intervention. ISPAD Annual Meeting, Miami. Pediatric Diabetes 2011: 12 (15S): pp S8
PUBLICATIONS:	Michelle Batthish, Ereny Bassilious, et al. A Unique, Interactive and Web-Based Pediatric Rheumatology Teaching Module: Residents' Perceptions. Pediatric Rheumatology 2013 11:22 doi:10.1186/1546-0096-11-22 The Hospital for Sick Children Handbook of Pediatrics 11th Edition, Co-editor, Hospital for Sick Children, Toronto, Ontario, Canada, 2007