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Adherence and Glycemic Control in Adolescents with Type 1 Diabetes: The Moderating Role of Age, Gender, and Family Support

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Abstract
Adherence and glycemic control usually decrease during adolescence and family relationships influence diabetes outcomes. This study analyzed the interaction effect of adolescents' family support, age, and gender in the relationship between adherence and glycemic control in adolescents with Type 1 Diabetes. The sample included 100 adolescents with Type 1 Diabetes and one of their parents during a routine endocrinology appointment. Adolescents answered the Self-Care Inventory—Revised, the Diabetes Family Behavior Scale and were also assessed on the glycosylated hemoglobin. The three-way interaction between adherence, family support, and adolescents' age/gender was both negatively significant and explained 24.12% and 22.02% of the variance, respectively. Higher family support, being female, and younger age moderated the relationship between adherence and glycemic control. According to results, it is important that intervention programs provide negotiation skills, according to adolescent's age and gender in the process of transferring diabetes management responsibility in order to promote better adherence to diabetes self-care, glycemic control, and prevent family conflicts regarding diabetes management.

Keywords Adherence · Glycemic control · Family support · Age and gender of adolescents · Type 1 Diabetes

Introduction

Type 1 Diabetes (T1D) is one of the most common chronic diseases in adolescents (Simmons & Michels, 2015), and in the last years in 26 European countries, the incidence rate of T1D revealed an increase of 3.4% per year (Patterson et al., 2019). A different scenario is occurring in Portugal, where the incidence rate of T1D is decreasing, being 11.5 cases of T1D for 100,000 individuals aged between 0 and 19 years old in the year of 2015, less than the incidence estimated for the year of 2014, that was 15.1 cases of T1D for 100,000 individuals in the same age range (Sociedade Portuguesa de Diabetologia (SPD), 2016).

The therapeutic regime of T1D in adolescents is complex and multifaceted and begins early with the illness onset impacting all family members' routines (Greening, Stoppelbein, & Reeves, 2010). Treatment tasks include monitoring of blood glucose, insulin injections at least four times a day, respecting the dietary plan, carbohydrate intake portion counting, and regular exercise (DiMeglio et al., 2018). The treatment goals involve the maintenance of an optimal glycemic control, which allows the prevention of diabetes complications (Donaghue et al., 2018).

During adolescence, adherence to diabetes treatment suffers a serious decline (Borus & Laffel, 2010), which consequently increases the risk for the development of complications and negatively influences the quality of life of adolescents (Silverstein et al., 2005). The complexity of diabetes treatment tasks may be overwhelming to adolescents, who are also involved with normative developmental challenges that include the gradual process of acquiring independence and autonomy from parents, the development of identity and self-esteem, and the creation of social bonds with peers (Williams, Sharpe, & Mullan, 2014).

To better understand the process of adaptation of adolescents with T1D, Whittemore, Jaser, Guo, and Grey,

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(2010) developed a framework that provides the individual and family factors influencing that process. According to this model (Whittemore et al., 2010), metabolic control and quality of life are both components of the adaptation to T1D in adolescents, which includes age and gender as some individual and family member's characteristics and family support as family response's factors influencing diabetes management and control.

The relationship between family support, age, and gender of adolescents with T1D in adherence and glycemic control will be described next.

Adherence to Self-Care and Glycemic Control

Adherence behaviors related to diabetes are not the only factors which may influence glycemic control in adolescents (Cohen, Lumley, Naar-King, Partridge & Cakan, 2004). Other factors include the influence of hormonal changes characteristic of puberty, which may interfere with adolescents' insulin resistance (Hamilton & Daneman, 2002), and consequently resulting in poor behavior adherence (Borus & Laffel, 2010), and family conflicts that may negatively influence glycemic control (Hochhausser, Rapaport, Shemesh, Schmeidler, & Chemtob, 2008). However, Cohen et al. (2004) found a positive relationship between adherence and glycemic control in adolescents with T1D.

Family Support, Adherence, and Metabolic Control

In turn, the quality of the interactions between parents and adolescents influence diabetes management, which may interfere with adherence and glycemic control (Borus & Laffel, 2010). The literature has shown how negative family environments and its interactions were associated with poor adherence and glycemic control in adolescents (Jaser & Grey, 2010; Lewin et al., 2006). The quality of the family environment such as cohesive, structured, supportive, and parental supervision were related to adolescents' adherence and glycemic control, and the decline in family interactions and supervision was associated with worst diabetes outcomes (Zhang et al., 2016; Cohen et al., 2004).

Adolescents' Age and Gender, Adherence, and Family Support

The feeling of invincibility and immortality that characterizes adolescence may interfere with diabetes management and result in difficulties in achieving a good glycemic control (Borus & Laffel, 2010). Also, the relationship between female and male adolescents with parental support is different (Stattin & Kerr, 2000), while female adolescents look for support and a protective role from parents when exposed to stress events, such as T1D, male adolescents often use the social support as a distraction from stress not seeking for parental emotional or instrumental support (Jackson & Warren, 2000). Family support and cohesion have a different influence in glycemic control of female and male adolescents, while in female adolescents, high family cohesion contributed to decrease female stress (lower glycemic values), in male adolescents, high family support was not related with better glycemic control (Cohen et al., 2004). Also, the fact that girls reported more ease in communicating and disclosing feelings with parents than boys (Stattin & Kerr, 2000; Jackson & Warren, 2000) may explain why female adolescents with diabetes who have better family support showed better adherence and glycemic control (Cohen et al., 2004).

In terms of adolescents' age, studies have shown differences between family relationships, adherence, and glycemic control in younger and older adolescents (Jaser & Grey, 2010; Neylon, O'Connel, Skinner, & Cameron, 2013; Wysocki et al., 2009). In older adolescents, family interactions characterized by parental criticism, such as nagging and negativity, were related to poor adherence and glycemic control (Jaser & Grey, 2010). In turn, in younger adolescents, diabetes management is still a task performed by parents, contributing to better adherence and glycemic control in these youths (Greening et al., 2010). Therefore, adolescents' age, gender, and family support, and their interrelationships emerge as vital in the study of adherence and glycemic control in T1D adolescents (Whittemore et al., 2010).

The goals of the present study included the analysis of the interaction of adolescents' age, gender, and family support in the relationship between adherence to self-care and glycemic control. It was hypothesized that better family support, being female and younger moderated the relationship between higher adherence and better glycemic control in T1D adolescents.

Materials and Methods

Study Design and Participants

One hundred adolescents with T1D and one of their parents participated in the study. This study utilized a cross-sectional

design and data were collected in two Portuguese urban hospitals. All adolescents had a T1D diagnosis, according to the International Society for Pediatric and Adolescent Diabetes (ISPAD) guidelines and complies with a self-monitoring of glucose throughout fingerstick blood glucose measurement (4 or more times *per* day) and an intensive insulin regime delivered by multiple daily injections (4 or more times *per* day (DiMeglio et al., 2018). Exclusion criteria included being diagnosed with a comorbid chronic disease or neurocognitive disorder, not being in an ambulatory regimen and using continuous glucose monitoring or pump therapy to insulin delivering. Of the total sample, 52% of adolescents were male, with a mean age of 15.12 years ($SD = 1.92$). 46% were in high school and had a mean duration of diabetes of 6.60 years ($SD = 3.77$). The average of glycated hemoglobin (HbA1c) was 9.1% ($SD = 1.61$), indicating high risk for the development of diabetes complications (Donaghue et al., 2018; DiMeglio et al., 2018). Approximately 88% and 90% of adolescents needed self-monitoring of glucose and administered insulin at least four times per day, respectively. Nearly 73% of adolescents lived with both parents (nuclear family), and 78% were accompanied by their mothers (primary caregiver), who had an average age of 44.51 years ($SD = 5.66$). 71% of parents had a full-time job and 25% had high school education level.

Procedure

The ethical committee boards of two Portuguese hospitals, where data collection took place, approved the study. Data collection took approximately 12 months. Adolescents and family members were invited by the adolescent's physician when the adolescent met the inclusion criteria. Participation was voluntary and parents and adolescents signed an informed consent and answered the questionnaires in a quiet room, in the hospital. When both parents accompanied the adolescent, only the family member designed as the primary caregiver, participated in the study. Adolescents' HbA1c values were measured by a nurse before the adolescents' medical appointment.

Measures

Self-Care Inventory-Revised (SCI-R; Weinger, Butler, Welch, & La Greca, 2005)

Adolescents completed a 14-item self-care inventory scale, which assessed adherence to diabetes behaviors over the previous month. The Portuguese version (Almeida & Pereira, 2010) was adapted to reflect the current diabetes standards. In this study, the global scale was used with a Cronbach's alpha of .73. Higher scores indicate better adherence to self-care.

Diabetes Family Behavior Scale (DFBS; McKelvey, Waller, North, Marks, Schreiner, Travis et al., 1993)

The scale assesses diabetes family behaviors that may help or hinder a child or adolescent in following their diabetes treatment regimen and asks adolescents to rate the frequency in which family support behaviors occur in their family. The Portuguese version (Almeida & Pereira, 2011) is a 33-item scale that yields a total score and two subscales—guidance control and warmth caring with Cronbach's alphas of .91 for the global scale, and .76 and .81 for the guidance-control and the warmth-caring subscales, respectively. Higher scores indicate less family support. In this study, the Cronbach's alpha was .83 and only the global scale was used, as in previous studies with the same population (Almeida & Pereira, 2011; Pereira, Almeida, Rocha, & Leandro, 2011).

Glycemic Control

Glycemic control was assessed by the value of HbA1c and this result represents the average of glycemic values of the last 3 months (DiMeglio et al., 2018). In accordance with the ISPAD guidelines and to prevent hypoglycemia or hyperglycemia (short-term diabetes complications), nephropathy, retinopathy or neuropathy situations (long-term diabetes complications), the results of HbA1c in adolescents must be above 7% (i.e., better glycemic control) (Donaghue et al., 2018). When HbA1c is higher than 9%, there is a higher risk for the development of diabetes complications. Thus, higher values of glycated hemoglobin indicate worse glycemic control.

Data Analysis

Multicollinearity between variables was tested and the variance inflation factor (VIF) calculated. VIF value was less than 3.0 ensuring data reliability (Daoud, 2017).

To assess differences according to adolescents' gender on adherence to self-care, family support, and glycemic control, a *t* test was used, and to assess the relationships between adolescents' age, adherence, family support, and glycemic control, bivariate correlations were calculated. Also, two moderate moderation analyses (three-way interactions) were conducted through a bootstrapping procedure (Dawson, 2014; Hayes, 2017) to examine if family support and adolescents' age or gender moderated the relationship between adherence and glycemic control. In each moderated moderation model, the two-way interactions and the three-way interactions need to be significant, and the 95% bias-corrected confidence intervals (CI) for the point estimate should not include zero to confirm both hypotheses (Hayes,

2017). To avoid the confounding effect of diabetes duration, considered as an important risk factor for the development of diabetes complications and its important cumulative effect on glycemic values over the duration of the T1D (Raile et al., 2007), this variable was included as a covariate in all moderation models.

The statistical package for the social sciences (SPSS, version 23.0) and the Process macro for SPSS (Hayes, 2017) were used to perform the analysis.

Results

No differences in adherence, family support, glycemic control, and adolescent's age were observed due to the adolescents' gender. Adherence was significantly and positively correlated with family support ($r = .527$; $p < .001$) and negatively related with glycemic control ($r = -.358$; $p < .001$), i.e., higher adherence was related to less family support and better glycemic control (lower glycated hemoglobin). The relationship between family support and glycemic control, and between family support and adolescents' age were both significant and negative ($r = -.255$; $p < .05$; $r = -.235$; $p < .05$, respectively) i.e., less family support was associated with better glycemic control and younger age.

Moderated Moderation Analysis

To analyze the moderation effect of family support in the relationship between adherence and glycemic control was significantly moderated by adolescent's age, a moderated moderation model was employed. The overall model explained 24.19% of the variance [$F(8,91) = 3.629$; $p = .010$]. All two-way interactions, i.e., Adherence X Family Support ($b = .015$; SE = .005; $p = .007$), Adherence X Adolescents' Age ($b = .106$; SE = .039; $p = .008$), and Family Support X Adolescents' Age ($b = .069$; SE = .027; $p = .011$) were positively significant. The three-way interaction Adherence X Family Support X Adolescents' Age was negatively significant ($b = -.001$; SE = .000; $p = .010$) and accounted for 5.7% of additional explained variance [$F(1,91) = 6.873$; $p = .010$], i.e., a significant interaction effect between age and family support was found in the relationship between adherence and glycemic control ($t = -3.191$; $p = .002$; Lower Limit of the 95% Confidence Interval [LL 95% CI] −.121; Upper Limit of the 95% Confidence Interval [UL 95% CI] −.028). Therefore, in younger adolescents with higher family support, better adherence was associated with better glycemic control (lower glycated hemoglobin values) (see Table 1; Fig. 1).

The moderated moderation model regarding adolescents' gender explained 22.63% of the variance [$F(8,91) = 3.327$; $p = .002$]. In this model, all two-way interactions were positively significant (Adherence X Family Support ($b = .003$; SE = .001; $p = .013$), Adherence X Adolescents' Gender ($b = .427$; SE = .190; $p = .027$), and Family Support X Adolescents' Gender ($b = .333$; SE = .136; $p = .017$). The 3-way interaction between Adherence X Family Support X Adolescents' Gender had a negative and significant effect ($b = -.004$; SE = .002; $p = .025$), i.e., a significant interaction was observed between adolescents' gender and family support in the relationship between adherence and glycemic control. The variance explained by this final model increased by 4.44% [$F(1,91) = 5.225$; $p = .025$]. Therefore, in female adolescents, better adherence was significantly related with better glycemic control when family support was perceived as high ($b = -.065$; SE = .024; $p = .010$) (see Table 2; Fig. 2).

Discussion

This cross-sectional study attempted to analyze the moderating effect of adolescents' age, gender, and family support in the relationship between adherence and glycemic control. The results confirmed both hypotheses that adolescents' age and gender significantly interacted with family support in the relationship between adherence and glycemic control. The relationship between better adherence and glycemic control was observed in younger adolescents and in female adolescents with better family support. No prior research, to the authors' knowledge, has analyzed the interaction between family support and adolescents' demographic characteristics, such as age and gender, in the relationship between adherence and glycemic control. These findings corroborate the conceptual model of Whittemore et al., (2010) about the process of adaptation in T1D. According to the model (Whittemore et al., 2010), the age and gender of adolescents can influence diabetes outcomes, such as adherence to self-care and metabolic control. Additionally, the quality of family interactions, the presence of conflict between parents and adolescents, and the shared responsibility of and support with diabetes tasks are widely recognized as having an impact in adherence and glycemic control (Whittemore et al., 2010). In children and young adolescents, the dependence on parents to support and guide their diabetes management is high, with mothers assuming the responsibility and control for diabetes management (Greening et al., 2010; Moore, Hackworth, Hamilton, Northam, & Cameron, 2013). As adolescents grow older, they are prone to become less dependent on their parent's supervision and more confidant in following their own decisions regarding diabetes management (Greening et al., 2010). However, during adolescence, more control from the mothers was in fact related to poor adherence, being perceived by the older

Table 1 The interaction effects of family support and adolescent's age in the relationship between adherence and glycemic control

Variables		*b*	SE	*t*	*p*	LL 95% CI	UL 95% CI
Const.		143.214	44.076	3.249	.002	55.661	230.766
Family support	M	−1.119	.401	−2.791	.006	−1.916	−.323
Adherence	X	−1.735	.593	−2.925	.004	−2.913	−.557
Adherence X Family Support	Int. 1	.015	.005	2.781	.007	.004	.025
Adolescent' age	W	−8.117	2.915	−2.784	.007	−13.908	−2.324
Adherence X Adolescent's Age	Int. 2	.106	.039	2.709	.008	.028	.184
Family Support X Adolescent's Age	Int. 3	.069	.027	2.603	.011	.016	.122
Adherence X Family Support X Adolescent's Age	Int. 4	−.001	.000	−2.622	.010	−.002	−.000
Diabetes duration		−.013	.044	−.284	.777	−.100	.075
Conditional effect of adherence on glycemic control at values of the moderators							
Adolescent's age	Family support						
Younger adolescents	Higher family support	−.076	.024	−3.157	.002	−.124	−.028
	Lower family support	.002	.028	−.053	.958	−.057	.055
Older adolescents	Higher family support	−.020	.019	−1.078	.284	−.057	.017
	Lower family support	−.049	.026	−1.853	.067	−.102	.004
Conditional effect of Adherence X Family Support at values of Adolescent's Age							
Adolescent's age							
Younger adolescents		.003	.001	2.501	.014	.001	.005
Older adolescents		−.001	.001	−.872	.385	−.003	.001

Const. constant, *M* first moderator variable, *X* independent variable, *Int.* interaction, *W* second moderator variable, *LL 95% CI* lower limit of the 95% of confidence interval, *UL 95% CI* upper limit of the 95% of confidence interval

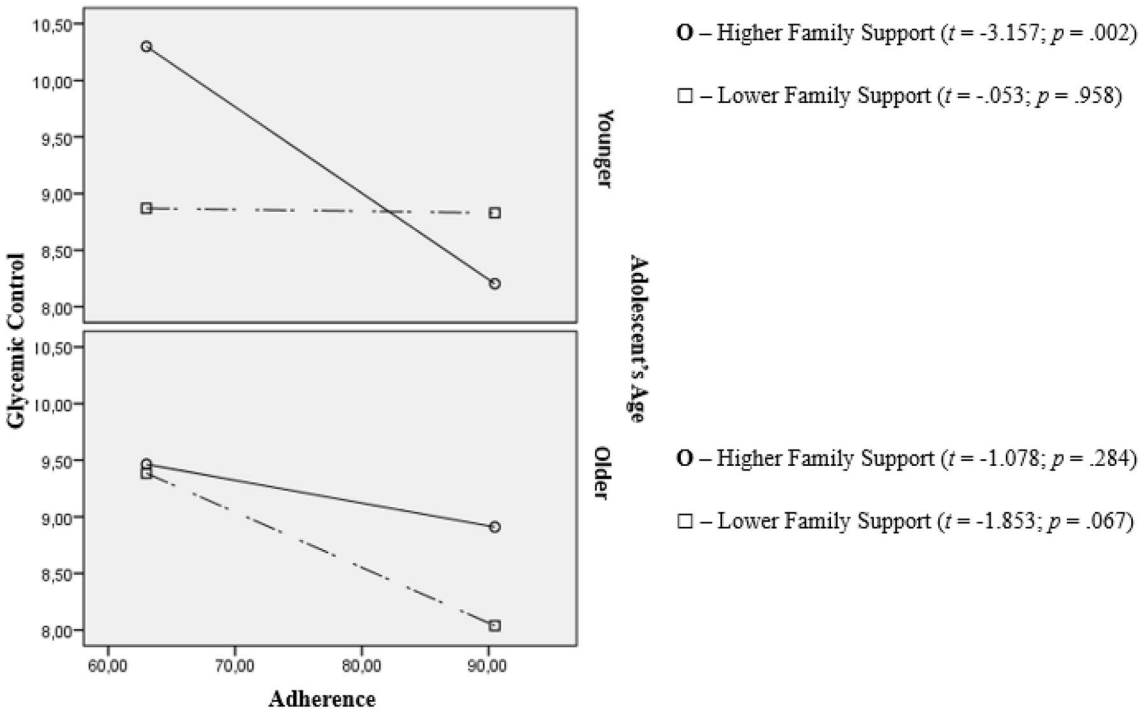

Fig. 1 The effects of adolescent's age, family support, and adherence on glycemic control, separately for the younger and older adolescents. This figure shows the effect of adolescent's age separately for high and low family support on the negative relationship between adherence and glycemic control among adolescents with T1D

Table 2 The interaction effects of family support and adolescent´s gender in the relationship between adherence and glycemic control

Variables		*b*	SE	*t*	*p*	LL 95% CI	UL 95% CI
Const.		43.217	11.257	3.839	.000	20.856	65.577
Family support	M	−.284	.105	−2.699	.008	−.493	−.075
Adherence	X	−.401	.145	−2.765	.007	−.689	−.113
Adherence X Family Support	Int. 1	.003	.001	2.521	.013	.001	.006
Adolescent' gender	W	−36.536	14.783	−2.472	.015	−65.902	−7.171
Adherence X Adolescent' Gender	Int. 2	.427	.190	2.244	.027	.049	.804
Family Support X Adolescent's Gender	Int. 3	.333	.136	2.442	.017	.062	.603
Adherence X Family Support X Adolescent's Gender	Int. 4	−.004	.002	−2.286	.025	−.007	−.001
Diabetes duration		−.034	.040	−.849	.398	−.114	.046
Conditional effect at values of adolescent's gender							
Adolescent's gender	Family support						
Female	Higher family support	−.065	.024	−2.649	.010	−.113	−.016
	Lower family support	.034	.037	.926	.357	−.039	.107
Male	Higher family support	−.032	.020	−1.598	.114	−.072	.008
	Lower family support	−.049	.025	−1.968	.052	−.099	.001
Conditional effect of Adherence X Family Support at values of Adolescent's Gender							
Adolescent's gender							
Female		.003	.001	2.521	.013	.001	.006
Male		−.001	.001	−.531	.597	−.003	.002

Const. constant, *M* first moderator variable, *X* independent variable, *Int.* interaction, *W* second moderator variable, *LL 95% CI* lower limit of the 95% of confidence interval, *UL 95% CI* upper limit of the 95% of confidence interval

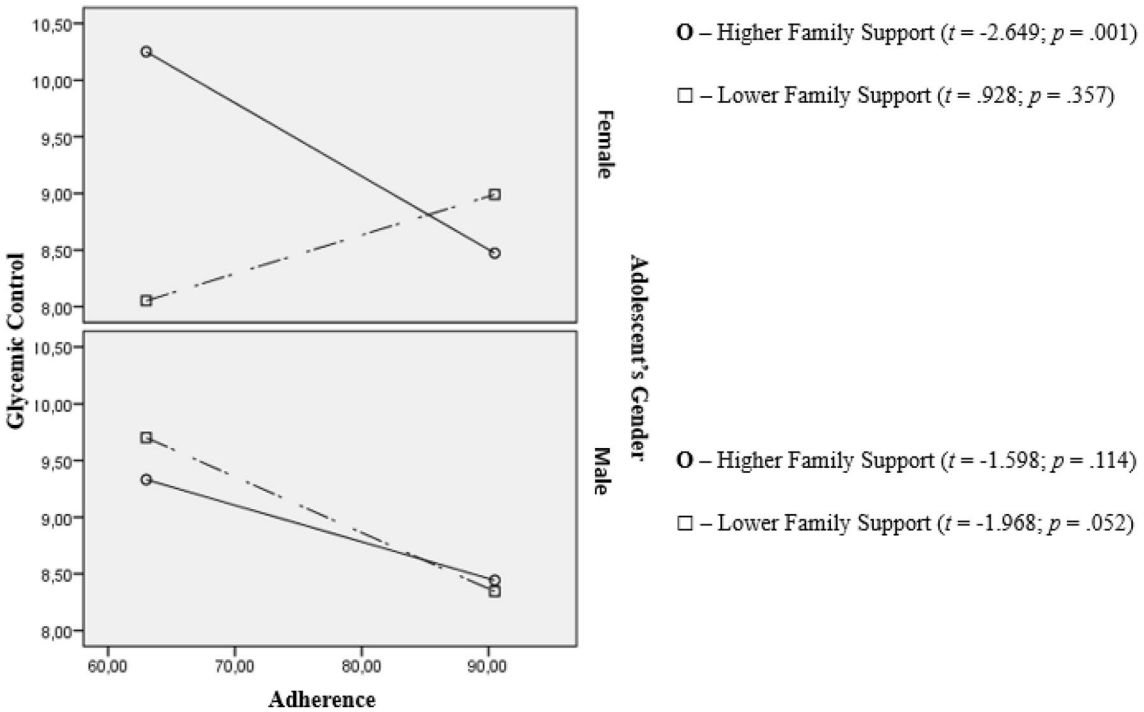

Fig. 2 The effects of gender, family support, and adherence on glycemic control, separately for the female ($n=48$) and male ($n=52$) adolescents. This figure shows the effect of adolescent's gender separately for high and low family support on the negative relationship between adherence and glycemic control among adolescents with diabetes

adolescent as critical while a collaborative interaction was a predictor of better adherence (Wysocki et al., 2009; Armstrong, Mackey, & Streisand, 2011). Also, adolescents' perception regarding the shared responsibility for diabetes management with parents was a predictor of glycemic control, in older adolescents (Helgeson, Reynolds, Siminerio, Escobar & Becker, 2008). Moreover, poorer family support, less responsibility in diabetes management, and more conflicts between parents and adolescents were predictors of worse self-care adherence and glycemic control, in adolescents (Neylon et al., 2013). Ellis et al., (2007) reported that parental monitoring and parental presence, in diabetes-specific care, were associated with higher adherence and, consequently with better glycemic control, being also important to prevent other health risk behaviors in adolescents. Furthermore, parental support on daily diabetes tasks predicted self-care adherence in adolescents (La Greca & Bearman, 2002; Pereira, Berg-Cross, Almeida & Machado, 2008).

During adolescence, the family conflict may increase, which may explain the lower adherence and glycemic control of adolescents (Hochhausser et al., 2008). Not only the hormonal changes of puberty contribute to higher levels of insulin resistance, but also the transference of the responsibility for diabetes self-care from parents to adolescents and peer group pressure may negatively interfere with diabetes management tasks (Hochhausser et al. 2008). Additionally, higher family support and involvement in diabetes tasks can lead to more opportunities to conflict situations related to diabetes management between parents and adolescents, which can explain why older adolescents showed worse diabetes outcomes (Pendley et al., 2002; Neylon et al., 2013; Pereira et al., 2008).

Although some studies showed gender differences in adherence and glycemic control of adolescents with diabetes (Neylon et al., 2013), the relationship between gender, adherence, and glycemic control is inconsistent. In Korbel, Wiebe, Berg, and Palmer's study (2007), female adolescents showed worse glycemic control, while Naar-King, Idalski, Ellis, Frey, Templin, Cunningham et al., (2006) found that males had lower self-care adherence when compared to females. Cohen et al. (2004) found that children' gender did not moderate the relationship between family cohesion or adaptability and adherence, but the relationship between these family variables and glycemic control were dependent on the child's gender and age at follow-up, i.e., higher family cohesion and low family adaptability were predictor of better glycemic control in female and younger adolescents, respectively. Girls tend to benefit from family support to control and reduce stress related to diabetes management (Jackson & Warren, 2000; Cohen et al., 2004), report more negative psychosocial problems (i.e., depression), and, additionally, communicate and share feelings with parents more easily than boys (Stattin & Kerr, 2000).

Clinical Implications

The results highlight two major areas for psychological interventions. It appears crucial that both parents and adolescents become involved in diabetes management, improved diabetes management skills, and increase problem-solving competences, in order to improve adherence behaviors and glycemic control and preventing diabetes complications and family conflict. Thus, it is important to develop intervention programs that improve diabetes management skills and increase problem-solving competences of adolescents and parents, since supportive and collaborative parenting styles in diabetes management contribute to adherence, as Ellis et al., (2007) found. Since there are age and gender differences both in the experiences of family support for adolescents and in diabetes outcomes (Pereira et al., 2008), it is important to provide negotiation skills, according to adolescent's age and gender in the process of transferring diabetes management responsibility. Intervention should also focus on how adolescents and parents may share diabetes tasks and problem-solving competences in order to promote better adherence to diabetes self-care and prevent conflicts. It is important that families are also capable of recognizing if the adolescent develops the skills and competencies to manage their diabetes during the adolescence stage. Parents and adolescents should work together to facilitate the adolescent's diabetes skills acquisitions.

Training diabetes educators into the health care team will facilitate and improve the process of diabetes management by the adolescent and family and will help identify the needs of each one contributing to decrease the discrimination and lack of opportunities related to the family's social economic situation.

Limitations and Future Research

This study presents some limitations, such as the cross-sectional design that does not allow to establish causal relationships between the variables and the small sample size. Future research should use a longitudinal design to study on how the relationships between adolescents and parents change during adolescence and its importance on adherence and glycemic control. It is also important to analyze parents' and adolescents' perceptions regarding adolescent's adherence and glycemic control.

Conclusion

During adolescence, adherence to self-care and glycemic control usually decrease and the relationships between adolescents and parents and how they relate with diabetes management also change, generating often conflicts that may add to worst diabetes outcomes. The findings showed that higher family support, being female and younger were moderators in the relationship between adherence and glycemic control. The results of this study lend therefore support to the clinical importance of interventions attending to the age and gender of adolescents and be family based since family support was shown to be crucial in adolescent's adherence to self-care and glycemic control across cultures.

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Compliance with Ethical Standards

Conflict of interest Ana C. Almeida, M. Engrácia Leandro, and M. Graça Pereira declare that there is no conflict of interest.

Human and Animal Rights All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional research committee of the two Portuguese hospitals (Process no. 68-CHLC) and with the 1964 Helsinki Declaration and its later amendments.

Informed Consent All parents and adolescents signed an informed consent to participate in this study.

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