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Research article

Lifestyle and physical fitness in adolescents with type 1 diabetes and obesity

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ABSTRACT

Background: The association between Type 1 Diabetes Mellitus (T1DM) and obesity (Ob) is no longer unexpected due to unhealthy lifestyle mostly in adolescents. We compared clinical-biochemical characteristics, adherence to the Mediterranean Diet (MD), lifestyle habits and physical fitness across different weight categories of T1DM adolescents from Campania Region. As second aim, we assessed the relationship among lifestyle and physical fitness in these patients.
Methods: 74 adolescents (35M; 39F; 13–18 y), with T1DM diagnosed at least 6 mo before the study, were enrolled at the Regional Center for Pediatric Diabetology of Vanvitelli University of Naples. Height, weight, Body Mass Index (BMI), BMI z-score, and Clinical Biochemical health-related parameters were determined. MD adherence, physical activity (PA) amount and sedentary habits were assessed by questionnaires. Handgrip strength, 2-Min Step test (2-MST) cardiorespiratory endurance and Timed up and go test (TUG) for agility and balance were used for physical fitness evaluation.
Results: Our sample included 22 normal weight (NW), 37 overweight (OW) and 15 with Obese (Ob) adolescents. Across the three groups, adolescents showed similar Clinical-Biochemical parameters, MD adherence, PA amount, mostly walking (9.3 h/w), daily video exposure (8.5 h/d) and similar handgrip or 2-MST performance. Better performance was observed in NW compared to OW or Ob for TUG (7 *vs* 8 *vs* 9 s; $p < 0.05$). A positive correlation was found between TUG test and BMI, while no correlation was found between HbA1c (glycated haemoglobin) and BMI z score or 2-MST.

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Conclusions: T1DM adolescents did not meet the recommendations for active lifestyle, despite a medium/good adherence to MD, in particular in NW and OW youths. Sedentary habits correlated with a poor HbA1c. Further, reduced agility and balance were observed in adolescents with obesity compared to NW participants.
Future research should be aimed to examine wider samples and to design health promotion interventions for T1DM adolescents.

1. Introduction

Until a few years ago, the association between type 1 diabetes mellitus (T1DM) and obesity was unexpected. In the last three decades, the prevalence of obesity in children and adolescents in developed countries has reached epidemic proportions considering the excessive consumption of energy-dense foods and sedentary lifestyle [1,2]. These factors led to the development of obesity even in T1DM adolescents who, unlike the normal population, need insulin therapy, and have to be often overinsulinized to achieve good glycemic control.

In this regard, intensive insulin treatment may be associated with weight gain and abdominal adiposity [3–5]. T1DM can significantly influence adolescents' lifestyle and represents a limit to participation in physical activity (PA) and sport practice due to the fear of hypoglycemia [6]. However, there are evidences on beneficial effects mediated by regular physical activity on glycemic control overcoming the risk of hypoglycemia [7–11]. Furthermore, evidences have been provided that recommend PA in the management of T1DM, considering regular PA a useful tool to prevent overweight/obesity and cardiovascular diseases [12,13].

On the other hand, sedentary behavior is predominant in childhood and adolescence; it may contribute to the development of obesity, encouraging a self-perpetuating vicious circle [14–16] that undermines the future metabolic health [17].

Regular PA improves metabolic and cardiorespiratory fitness in youths [18,19], prevents weight gain and it is one of the lifestyle components that has been demonstrated to reduce the risk of cardiovascular disease and chronic not-communicable diseases (NMCD) lifelong [20]. Recently the World Health Organization recommended the minimal dose of daily PA that should be done alongside the life in order to prevent lifestyle diseases; in particular, for children and adolescent, a minimum of 60 min of daily moderate-to vigorous-intensity, mostly aerobic physical activity, for at least 3 days a week are recommended [21]. PA is considered one of the four cornerstones of diabetes treatment, alongside heathy diet, glucose monitoring, and insulin-based management, for achieving adequate glycemic control. Clinical guidelines for exercise are still evolving for adolescents with T1DM, since they are mostly based on evidences on patients with type 2 diabetes (T2DM) [22]. PA is the main determinants of physical fitness that includes different components, such as aerobic fitness and strength [23–25] which are considered important markers of health [26].

It would be valuable to assess whether physical fitness, PA levels and healthy eating habits such as adherence to the Mediterranean Diet (MD) pattern, are associated to weight excess in adolescents with T1DM.

Therefore, we aimed to analyze: (1) clinical-biochemical characteristics, (2) adherence to the MD, (3) PA levels and sedentary time, and (4) physical fitness according to different weight categories in T1DM adolescents. As second aim, we assessed the relationship among lifestyle and physical fitness in these patients.

2. Materials and methods

2.1. Sample and setting

The present study has a cross-sectional design including adolescents between 13 and 18 years of age with T1DM, who were receiving routine care at a university-based "Regional Center for Pediatric Diabetology "G. Stoppoloni", Integrated Maternal and Child Care Department of University of Campania "Luigi Vanvitelli" in Naples. Participants were required to have a diagnosis of T1DM for at least 6 months and no disabling comorbidities. Adolescents were scheduled for a morning appointment after an overnight fast of at least 10 h. First, anthropometric measurements and fasting laboratory tests were carried-out. Thereafter, adolescents were given a light breakfast and answered the questionnaire administrated by the researchers on MD adherence (KIDMED) and PA level (IPAQ-A). At the end of interview the adolescents were assessed by specific fitness test (see below). The testing procedure occurred approximately 1 h after admission to the Clinical Research Center. The participants and their parents or legal guardians signed an informed consent term. Ethics committee on human research of the Clinical Hospital "Luigi Vanvitelli" approved the study (reference 338/2019 University of Campania "Luigi Vanvitelli", AOU "Luigi Vanvitelli", AORN "Ospedale dei Colli", Napoli).

2.2. Anthropometric measurements

Height was measured by a stadiometer to the nearest 0.1 cm without shoes. Weight was measured by a calibrated scale (SECA 710) with 100 g resolution. To assess the nutritional status, the BMI z-score was calculated, based on the criteria of the World Health Organization (WHO), by the WHO Antro Plus 10.4 program. Considering the WHO's references, z-scores $<-2SD$, $\geq+1SD$, $\geq+2SD$ for BMI indicated thinness, overweight, and obesity, respectively [27]. Waist circumference (WC) was measured to the nearest 0.1 cm at the end of normal expiration at the midpoint between the iliac crest and the lower borders of the rib cage. Waist-To-Height Ratio (WHtR) was calculated as WC (cm) divided by height (cm). Mid-upper arm circumference (MUAC) and triceps skinfold thickness (TST) were taken with the participant stand upright, the arm should be freely hanging from side to side without stretching his/her arms and the researcher was behind the participant taking the measurement. Arm circumference was taken with tape measure and the triceps skinfold thickness measurement was taken with the skinfold (Skinfold Caliper, Holtain Ltd., UK) over the triceps muscles in the middle of the upper arm (between the acromion and olecranon points). The equations of the mid-arm muscle and fat area were drawn from the equations of Frisancho [28] calculating the arm muscle area (AMA) and the arm fat area (AFA).

2.3. Clinical-biochemical parameters

Blood samples, drawn from a forearm vein, were collected after 10 h of fasting. Glucose, glycated hemoglobin levels (HbA1c), total cholesterol, low-density lipoprotein cholesterol (LDL-c), high-density lipoprotein cholesterol (HDL-c), triglyceride, alanine aminotransferase (ALT), aspartate aminotransferase (AST) and gamma-glutamyltransferase (GGT) levels were assessed.

2.4. Adherence to the Mediterranean Diet

The KIDMED score was used to assess the adherence to the MD [29]. This score is based on 16 items, one point was given to answers representing positive food habits (items 1–5, 7–11, 13, 15), and one point was subtracted for those representing negative food habits (items 6, 12, 14, 16). Three categories of adherence (poor, average and good) were defined according to a score <3, between 4 and 7 and ≥ 8, respectively.

2.5. Physical activity levels

The short form of International Physical Activity Questionnaire in Adolescents (IPAQ-A) was used to assess physical activity levels in the volunteers [30]. This questionnaire measures the type and amount of PA usually performed. The items refer to the activity carried-out in the last 7 days at home, at school, to move from one place to another and in free time. It includes 11 items for each of which, the participants were asked to indicate the weekly frequency of each activity and the duration.

In addition, the section of the health behaviors related to the PA of the “Health Behavior in School-aged Children” questionnaire was used [31]. The items were: (1) how many hours do you watch tv every day?; (2) how many hours do you use videogames every day?; (3) how many hours do you use internet (pc, smartphone, tablet) every day?; Lastly, the following questions were included about sports participation: (6) do you play any sport?; (7) which kind of sport?; (8) how many session in a week?; (9) how many minutes each session?

The training volume was then calculated by multiplying minutes/session × number of sessions/weeks.

2.6. Physical fitness assessment

To assess physical fitness status of volunteers we used *handgrip strength*; *2-min step test* (*2-MST*) and *Timed up and go test (TUG)* [32, 33]. All the tests were explained by a researcher before to start and all the participants familiarized with the test before the administration.

The *handgrip test* was performed in order to measure the maximum isometric handgrip strength, recognized as an important health indicator for determining musculoskeletal function, as well as weakness [34]. Before the measurements, all the participants familiarized with the dynamometer and were encouraged by the researchers to perform at the maximum effort during the test. Each participant performed three measurements of the maximum isometric handgrip strength on a dynamometer (Jamar Hydraulic Hand Dynamometer) sitting on a chair, at a 90° angle, with shoulder blades immobilized in the back, head in neutral position, alternatively with the dominant hand and the non-dominant hand. A rest of 1 min was given between each measurement. All measurements were taken by the same researcher and recorded in kg with a decimal point. The medium value of the three measurement was considered for the analysis.

The 2-MST is an aerobic endurance test validated as a functional test [32–35]. The measurement protocol provides for the determination of the greatest possible number of times an individual can get on and off the device in a single 20 cm step during 2 min, without handles [36]. Researcher gave the start signal “go” and started to count the total number of ascents and descents, informing the participant of the time as it passes (i.e., “2 min,” “1 min,” “30 s left,” etc.).

The *TUG* belongs to the senior fitness tests and it is used to assess dynamic balance, as agility in frailty [37] and also used in adolescents with obesity [38]. It is a composite measure involving dynamic balance, speed and agility. The protocol involves getting out of a chair, walking 3 m, turn around a cone and returning to the chair in the shortest time possible. These instructions were clearly communicated to the participants. The researcher gave the start “go” signal and at the end of the trial the test score (in seconds) was used for the analysis [39].

2.7. Statistical analysis

Statistical analyses were performed using the Statistical Package for Social Sciences (SPSS Inc, Chicago, IL, USA) version 26. Statistical significance was pre-determined as $p < 0.05$.

The Shapiro-Wilks normality test was applied to assess the normality of data distribution. The variables that had a non-parametric distribution were expressed as medians and interquartile range, while those that had normal distribution were expressed as mean and standard deviation. The ANOVA (parametric data) or the Kruskal-Wallis test by rank (skewed data) were performed for comparisons among groups, using the *post-hoc* Dunn-Bonferroni approach for pairwise comparisons. The Spearman's Rank Correlation test was applied to assess the association between the results of fitness tests and the variables of interest. The *chi-square* test of independence was used to determine the association between categorical variables; Fisher's Exact Test was used when one or more of the cell counts was less than 5.

3. Results

On the total sample of patients receiving routine care at the Regional Center for Pediatric Diabetology "G.Stoppoloni", in Naples, for the age range 13–18, 90 agreed to participate; 74 met the inclusion criteria, divided in 39 females and 35 males, the mean age was 14.7 ± 1.6 years, 22 presented normal-weight, 37 overweight and 15 obesity. Table 1 shows anthropometric differences among the three groups. Normal weight participants showed significantly lower values of WHtR, MUAC, TST and AFA compared to individuals with overweight or obesity, while the AMA in the normal weight group was significantly lower than that of the group with obesity.

As shown in Table 2, no differences were found for Clinical- Biochemical data among the three groups.

As for the MD adherence, the overall medium score was 5.9 ± 3.1; 21.6% of the sample obtained a score ≤3 indicating low adherence, 37.9% obtained a score comprised between 4 and 7, indicating medium adherence and the remaining 40.5% showed good adherence. No differences were found among groups ($p = 0.726$), although the adolescents with obesity showed a lower score (5.4 ± 2.9) compared to normal weight (6.1 ± 3.1) and overweight individuals (6.1 ± 3.1).

Looking at the amount of PA assessed by the IPAQ-A (Table 3), no differences were evidenced among the three groups: the total amount of time spent in overall PA was 7.75 h/week. The 52.4% of the adolescents with normal weight, 55.6% of those with overweight and 42.9% of those with obesity declared to regularly play sport, gym practice, football, volleyball and swimming were the regular activities reported. Overall, the volume of training was 120 (0–270) minutes/week [subjects with normal weight 140 (0–270), with overweight 120 (0–270), with obesity 146 (0–270) minutes/week], without significant differences between groups (Kruskal Wallis: $p = 0.886$).

The analysis of specific sedentary behaviors did not show differences among the three groups (Table 4). The overall video exposure was 8 (6–11) hours/day with no differences between groups [subjects with normal-weight 8.5 (6.7–10.5), overweight 8 (6–12) and obesity 8 (5.7–10), $p = 0.582$].

The Kidmed score correlated positively with the PA levels ($r = 0.244$, $p < 0.05$) and the overall IPAQ-A questionnaire score ($r = 0.250$, $p < 0.05$). The overall IPAQ-A questionnaire score showed a negative correlation with the WHtR ($r = -0.266$, $p < 0.05$). Both Kidmed score and overall IPAQ-A did not show a significant correlation with HbA1c ($r = -0.178$, $p = 0.128$; $r = -0.044$, $p = 0.710$ respectively).

The overall video exposure showed a positive correlation with HbA1c levels ($r = 0.328$, $p < 0.05$).

The physical fitness assessment showed differences only for *TUG;* adolescents with normal weight performed better than those with obesity while no differences were found for the *handgrip* and the 2-MST (Table 5).

The 2-MST showed a direct correlation with sport practice ($r = 0.428$, $p < 0.001$), volume of training ($r = 0.362$, $p < 0.01$), time spent in moderate-vigorous physical activity ($r = 0.264$, $p < 0.05$), walking ($r = 0.234$, $p < 0.05$) and overall IPAQ-A score ($r = 0.305$, $p < 0.01$).

Further, the *TUG test* showed a direct correlation with BMI ($r = 0.231$, $p < 0.05$), WHtR ($r = 0.271$, $p < 0.05$), TST ($r = 0.348$, $p < 0.01$), AFA ($r = 0.412$, $p < 0.001$) and a negative correlation with HbA1c ($r = -0.249$, $p < 0.05$), and handgrip test results (right hand $r = -0.479$, $p < 0.001$; left hand $r = -0.425$, $p < 0.001$). The handgrip test showed a negative correlation, for both sides, with TST ($r = -.439$, $p < 0.001$; -0.402, $p < 0.001$ right and left, respectively) and AFA ($r = -0.475$, $p < 0.001$; -0.440, $p < 0.001$ right and left, respectively).

Table 1
Anthropometric characteristics of adolescents enrolled in this study.

	Total Sample	Normal Weight	Overweight	Obese	Sig.
Gender M/F	35/39	13/9	15/22	7/8	.299[a]
Age (yrs)	14 (13–16)	14 (13.8–17)	14 (13–16)	15 (13–16)	0.734[b]
Height (cm)	165 ± 10	167 ± 10	162 ± 10	166 ± 10	.108
Weight (kg)	66.2 ± 12.1	58.4 ± 11.4*	65.4 ± 7.7§§§	79.8 ± 10.9$^{###}$	$p < 0.001$
BMI (kg/m^2)	24.4 ± 3.7	20.8 ± 2.9***	24.6 ± 1.7§§§	29.0 ± 2.7$^{###}$	$p < 0.001$
BMI (z-score) (sd)	1.3 (0.8–1.8)	0.6 (−0.3-0.8)***	1.4 (1.3–1.6)§§§	2.3 (2.1–2.4)$^{###}$	$p < 0.001$[b]
WHtR (cm)	46 (43–49)	41 (38–43)**	47 (46–49)§	51 (47–53)$^{##}$	$p < 0.001$[b]
MUAC (cm)	25.7 ± 4.8	22.8 ± 3.1*	26.0 ± 3.4	28.7 ± 7.4$^{##}$	$p < 0.01$
TST (mm)	18.0 ± 7.0	12.7 ± 4.6**	18.5 ± 6.6§§§	23.8 ± 6.1$^{#}$	$p < 0.001$
AMA (cm^2)	32.9 ± 11	28.7 ± 8.3	32.9 ± 7.3	38.7 ± 18	$p < 0.05$
AFA (cm^2)	21.2 ± 11	13.4 ± 5.7*	21.3 ± 9.1§§	31.1 ± 12$^{###}$	$p < 0.001$

Abbreviations: WHtR = waist-to-height ratio; MUAC = mid-upper arm circumference; TST = triceps skinfold thickness; AMA = arm muscle area; AFA = arm fat area.

[a] chi square.

[b] skewed variables are expressed as median (interquartile range), while parametric variables are expressed as means ± SD. NW *vs* OW: *$p < 0.05$; **$p < 0.01$; ***$p < 0.001$; OW *vs* Ob: $^{§}p < 0.05$; $^{§§}p < 0.01$; $^{§§§}p < 0.001$; Ob *vs* NW: $^{#}p < 0.05$; $^{##}p < 0.01$; $^{###}p < 0.001$.

Table 2
Clinical-Biochemical characteristics of adolescents enrolled in the study.

	Total sample	Normal Weight	Overweight	Obese	*p*-value
HbA1c (mMol)	62.1 ± 7.1	63.2 ± 10.3	63.1 ± 6.6	63.3 ± 7.2	.990
AST (U/L)	16 (14–19)	16 (14–20)	16 (15–18)	16 (14–21)	.895[a]
ALT (U/L)	14.8 ± 6.6	14.3 ± 4.4	14.5 ± 7.7	16.2 ± 6.3	.681
GGT (U/L)	12 (9–16)	11 (10–16)	11 (9–14)	16 (11–17)	.139[a]
Cholesterol (mg/dL)	163.5 ± 26.5	156.9 ± 28.1	165.0 ± 25.3	169.1 ± 27.5	.379
LDL-C (mg/dL)	98.5 ± 24.5	85.8 ± 34.5	99.8 ± 23.8	97.3 ± 23.5	.519
HDL-C (mg/dL)	52.9 ± 10.3	54.4 ± 11.8	51.5 ± 9.2	53.9 ± 10.3	.650
Triglycerides (mg/dL)	69 (58–80)	65 (53–79)	70 (59–88)	68 (55–88)	.622[a]

[a] Skewed variables are expressed as median (interquartile range), while parametric variables are expressed as means ± SD.

Table 3
Physical activity amount in the total sample and across categories of BMI.

	Total sample	Normal weight	Overweight	Obese	*p*-value
Total PA min/week	465 (270–742)	530 (300–1068)	430 (290–678)	580 (250–820)	.407
Moderate -Vigorous PA min/week	185 (90–347)	160 (90–372)	190 (90–300)	220 (60–370)	.278
Walking min/week	225 (129–480)	305 (184–693)	200 (122–445)	210 (70–455)	.175

All the values are expressed as median (interquartile range).

Table 4
Sedentary behaviors of adolescents enrolled in this study.

Activity (h/day)	Total sample	Normal weight	Overweight	Obese	*p*-value
Television	0 (0–1)	1 (0–1.2)	1 (0–2)	1 (0.5–2)	.783
Videogames	0 (0–3)	0.5 (0–5)	0 (0–3)	0.8 (0–2.2)	.265
Internet	6 (4–8)	6 (4–8)	6 (4–8)	6 (4–9)	.775
Overall Video exposure	8 (6–11)	8.5 (6.7–10.5)	8 (6–12)	8 (5.7–10)	.582

All the values are expressed as median (interquartile range).

Table 5
Physical fitness of adolescents enrolled in the study.

	Total Sample	Normal weight	Overweight	Obese	*p*-value
Handgrip dx (kg)	44 (28–60)	47 (34–64)	39 (26–60)	40 (24–55)	.336
Handgrip sx (kg)	40 (25–58)	40 (33–54)	36 (22–61)	40 (24–48)	.696
2-MST (counts)	52 (45–62)	54 (45–63)	52 (48–65)	50 (41–53)	.425
TUG (seconds)	8 (7–10)	7 (6–8)*	8 (7–10)	9 (8–11)	.018

All the values are expressed as median (interquartile range); *$p < 0.05$.

4. Discussion

Children and adolescents affected by T1DM are more often overweight and obese than in the past [40].

We aimed to analyze whether the determinants related to diet and lifestyle differ between T1DM adolescents with obesity or normal weight, as it occurs in the population without diabetes. We evidenced a medium/good adherence to MD without significant differences among BMI groups in accordance to what has been observed in adolescents with obesity [41]. Also, no correlation was found for the adherence to MD and HbA1c levels, differently from that evidenced in T1DM Spanish children with high adherence to MD [42], since 53% of patients had an optimal adherence compared to 40% in our sample. This result could be ascribed to the different age range, since our sample was composed only of adolescents who might probably deviate from the MD model more frequently than children [43].

Our sample did not fulfill the guidelines for PA, i.e. at least 60 min/days of MVPA. Many studies support reduced PA levels in T1DM children and adolescents compared to their healthy peers [44–48], independently from insulin therapy [49]. On the contrary, an Italian multicenter study reported that most of T1DM youngsters interviewed were physically active and exercised at the same level as their healthy peers [50]. Furthermore, a recent multicentric study conducted in Italy evidenced that a combination of poor lifestyle choices, mostly low PA, was associated to lower diabetes-specific health related quality of life scores in adolescents and young adults with T1DM [51]. Comparing the results obtained in our study to that general adolescent population, periodically monitored by the Health Behavior in School-aged Children (HBSC) survey, no substantial differences emerged for time spent in PA. In fact, a median participation in MVPA for about 3 h/week was found in our study, which corresponds to the amount mainly reported by the Italian adolescents enrolled in the last HBSC survey [52]. As for screen time, however, the time spent in overall video exposure by HBSC participants was 1–2 h/day, which is much lower than the level declared by our participants about 8 h, without differences among BMI groups. These results are partially in line with the literature concerning healthy adolescents. In their systematic review, Elmesmari et al. reported a significant reduced time spent in MVPA in adolescents with obesity than in non-obese peers; on the contrary, only one third of the studies analyzing sedentary behaviors found significantly higher sedentary time in adolescents with obesity than in the non-obese peers [53]. Not surprisingly, we did not find any significant association between HbA1c and time spent in PA, while we found a significant association with overall sedentary time. Similar findings were reported in a large cohort of Swedish adolescents with T1DM [54]. Our results are also in line with a recent systematic review and meta-analysis evidencing that low-levels of PA and poor cardiorespiratory fitness as well as sedentary habits explain in part the variance of glycated hemoglobin (HbA1c) and the risk for poor glycemic control in T1DM youth [55,56].

Only few studies have assessed physical fitness in T1DM children and adolescents, specifically cardiorespiratory fitness [44,57], with conflicting results. Some investigations report that diabetic children and adolescents had lower cardiorespiratory function [58–60] and reduced fitness parameters compared with age matched healthy subjects [61]. Other studies found no significant differences in the aerobic exercise capacity (VO_{2max}) among diabetic or healthy children/adolescent groups [55,62,63].

Handgrip strength, a well-known indicator of muscle strength, has been associated with health outcomes such as lipid profile and glucose levels, particularly in OW and Ob children [64,65]. Data on handgrip strength in adolescents with T1DM compared to healthy pairs are limited and contradictory [66–68]. Moreover, no correlation was reported between handgrip strength and HbA1c in children and adolescents with T1DM [68]. In our study, we did not find differences in handgrip strength among BMI categories and lifestyle.

Most likely, the lack of differences between T1DM adolescent with NW, OW or obesity in our study may be due to the fact that patients with OW and obesity were immediately referred to a multidisciplinary team of nutritionists, diabetologists and psychologists, who provided counselling on reducing weight and encouraging PA in order to achieve a better glycemic control.

Maximal oxygen uptake (VO_{2max}) represents the standard parameter used for cardiorespiratory capacity and aerobic exercise evaluation [69]. Diabetes was associated to poor cardiorespiratory fitness and increased risk for co-morbidities as heart diseases and stroke and increased risk for mortality [70].

Some studies have been provided so far, including meta-analysis, evidences on the effects of sedentary, BMI z score and cardiorespiratory capacity and glycemic control in children/adolescent with no consistent results. In general, T1DM youths show reduced cardiorespiratory capacity compared to healthy controls; lower BMI-z score and involvement in MVPA exercise are associated to improved glycemic control [71,72].

The 2-MST or 3-MST represents a cardiopulmonary test used in older or obese individuals; recently, evaluation of 2-MST was also provided in children lean or with obesity [32,73,74]. The 2-MST or 3-MST performance positively correlated with 6 min walking distances, age, and body weight in healthy or T2DM patients [36,75]. The mean value obtained in 3-MST in 6–12 y healthy Spanish children was 124 steps. Albeit measured with 2-MST, our population was less performing than the healthy Spanish children, doing a mean of 52 steps. In addition, this result was lower compared to the optimal cut-off score <61 steps by 2-MST test found in T2DM elderly patients, which is predictive of poor cardiorespiratory fitness [75].

TUG test was first used to evaluate the dynamic balance and critical falls in older population [37,76]. Recently the TUG test was used in order to evaluate the agility and functional mobility in young populations, healthy (also related to BMI) or affected by neurological diseases [33,77,78].

In a cross-sectional study evaluating the relationship between skeletal muscle mass and PA in a schoolchildren population living in Osaka, Japan, the authors evidenced that children fulfilling the recommended levels of MVPA for Japanese population (60 min MVPA/day, 5 d/week) are more fit that children performing substandard dose of daily PA. In particular, they found stronger grip strength and faster TUG time in most active children (7.29 *vs* 7.62 s) [39]. We found a mean value of 8 s (in the whole sample) ranging from 7 to 10 s in agreement to that reported in the Japanese study. Interestingly, normal weight adolescents performed better (mean 7 s) compared to their peers with obesity (mean 9 s), independently of MVPA. Due to the fact that the TUG test assess functional mobility and balance function our results further support the thesis that muscle strength may be independent of MVPA [39,78].

In conclusion, this study evidenced that T1DM adolescents do not meet the minimum PA recommended for age, so as 60 min/day of MVPA, and only the 50% of sample was engaged in sport activities; T1D adolescents with obesity were mainly engaged in walking. Overall, our T1DM adolescents sample spent a lot of time in sedentary activities; on the other hand, they showed a medium/good adherence to MD, in particular NW and OW participants. Sedentary habits correlated with a poor HbA1c; reduced agility and balance were found in youths Obese compared to NW participants.

These results highlight that the type1 adolescent, we analyzed, are sedentary, in that they spent about 8 h/day in video exposure, and not fulfill the minimum physical activity recommendation (at least 60 min/day of MVPA). For this, it will be advised the presence of a chinesiologist in the multidisciplinary team that provide routine care at Regional Center for pediatric Diabetology in order to improve daily PA and reduce sedentary behavior in T1DM patients.

This is the first study aimed at analyzing physical fitness of T1DM adolescents from a region of southern Italy in relation to their anthropometric and biochemical characteristics and to their lifestyle. The limited number of examined patients represents the main limitation of this study, as well as the use of self -reported questionnaires about dietary and lifestyle habits.

Future research should be aimed to examine wider samples and to design health promotion interventions for T1DM adolescents.

Author contribution statement

Patrizia Calella: Performed the experiments; Analyzed and interpreted the data; Wrote the paper.
Daniela Vitucci: Analyzed and interpreted the data; Wrote the paper.

Angela Zanfardino; A. Serena Rollato; Francesca Gallè; Annamaria Mancini; Valeria Di Onofrio: Analyzed and interpreted the data.
Francesca Cozzolino; Alessia Terracciano; Francesco Zanfardino; Alessia Piscopo: Performed the experiments.
Dario Iafusco: Conceived and designed the experiments; Contributed reagents, materials, analysis tools or data.
Giuliana Valerio: Conceived and designed the experiments; Contributed reagents, materials, analysis tools or data; Wrote the paper.
Pasqualina Buono, PhD: Conceived and designed the experiments; Contributed reagents, materials, analysis tools or data; Wrote the paper.
Giorgio Liguori: Contributed reagents, materials, analysis tools or data.

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Data availability statement

Data will be made available on request.

Declaration of interest's statement

The authors declare no conflict of interest.

Additional information

No additional information is available for this paper.

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