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FIT FIRST teen – a cluster RCT evaluating the effects of a 10-week high-intensity exercise intervention for 12–15-yr-old school children

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ABSTRACT

Objectives: To evaluate the effects of a 10-week thrice-weekly FIT FIRST Teen (FFT) intervention on cardiorespiratory fitness in Danish 12–15-years-olds.

Design: A cluster-randomised controlled study.

Participants: One thousand four hundred and seventeen Danish pupils (51.1% female) from 15 municipal schools, allocated to an intervention group (FFT: $n = 994$, 13.5 (0.6) years (mean (SD)), 165.8 (8.7) cm, 57.8 (13.4) kg) or a usual practice control group (CON: $n = 423$, 13.8 (0.8) years, 167.7 (11.5) cm, 58.6 (12.2) kg).

Methods: The FFT group completed three weekly 40-min FFT sessions with modified, motivating, involving, high-intensity sports-based activities. Before and after the 10-wk intervention period resting heart rate and blood pressure, body composition, postural balance, standing long jump and performance on the Yo-Yo intermittent recovery level 1 children's test (YYIR1C) were measured. Group effects for all outcome variables were tested using multi-level linear mixed models.

Results: The group effect analyses showed no significant differences between FFT and CON in the YYIR1C test ($p = 0.080$). A significant small difference between groups was found in resting heart rate ($d = 0.29$, $p = 0.039$) in favour of FFT. No significant between-group differences were observed in body composition, or the remaining cardiovascular or physical fitness variables ($p > 0.05$).

Conclusion: The lack of significant effects for the majority of the outcome measures calls for further development and long-term testing of the programme.

KEYWORDS

Resting heart rate; muscle mass; body fat; ball games; school intervention; physical education

Introduction

Physical activity has consistently been proven to have preventive beneficial effects on physical health and fitness across the life span (Posadzki et al., 2020; Warburton & Bredin, 2017). The Danish Health Authorities and the World Health Organization, recommend an average of at least 60 minutes of daily MVPA across the week for children and adolescents up to the age of 18 years. This recommendation includes high-intensity activities and muscle strengthening activities three times per week (Sundhedsstyrelsen, 2023; WHO, 2020). Observational studies have shown a positive association between time spent in moderate-vigorous physical activity (MVPA) and several health outcomes such as high muscular and cardiorespiratory fitness (CRF) and favourable body composition (L. B. Andersen et al., 2011; Bangsbo & Krstrup, 2016; Carson et al., 2014; Ekelund et al., 2012; Poitras et al., 2016; WHO, 2020). Silva et al. found greater odds for being fit (measured by CRF-level) for adolescents complying with the 60-minute MVPA recommendations, compared to non-complying peers (Silva et al., 2013) while Hay et al. found the association

between PA time, and cardiometabolic risk factors to be significant only for time spent in VPA, and not for moderate or light intensities when studying Canadian children and adolescents (Hay et al., 2012). Further, Ortega et al. in their review concluded that increasing VPA levels should be a major goal in current and future public health promotion policies targeting children and adolescents (Ortega et al., 2008). A high level of PA, high physical fitness and a healthy BMI in children and adolescents reduce the risk of accumulating risk factors for non-communicable diseases (Bangsbo & Krstrup, 2016; Ekelund et al., 2012) and significantly lowers the risk of becoming overweight and obese in adulthood (Kvaavik et al., 2003; Sundhedsstyrelsen, 2023b). Furthermore, participation in school-based and leisure-time sports during childhood and adolescence increases the likelihood of being sufficiently physically active later in life (Batista et al., 2019; Huotari et al., 2011; Kvaavik et al., 2003; Menschik et al., 2008).

Data from the most recent Health-Behaviour in School-aged Children (HSBC) project (data collected in 2021–2022) showed that only one in four Danish boys and one in five

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Danish girls aged 11–15 met these recommendations (Christiansen et al., 2022; Toftager et al., 2023). Studies have showed socioeconomic disparities in physical activity levels (Falese et al., 2021), CRF and musculoskeletal fitness (Clennin et al., 2019; Finger et al., 2014; Wolfe et al., 2020) and obesity (M. B. Andersen et al., 2020; Elgar et al., 2015) with adolescents from families with low socioeconomic status (SES) being more likely to have lower VPA levels, fitness and a higher likelihood of adult obesity (M. B. Andersen et al., 2020; Clennin et al., 2019; Elgar et al., 2015; Falese et al., 2021; Finger et al., 2014; Wolfe et al., 2020) which increases their risk of chronic diseases such as type 2 diabetes, cardiovascular disease, and certain cancers (Reilly & Kelly, 2011). As children and adolescents spend a majority of their waking hours in school, the World Health Organization recommends a framework that includes school-based interventions to increase PA levels among children and adolescents across the SES spectrum (WHO, 2022). Previous intervention studies using school-based high intensity training in Denmark have shown improvements in CRF (Bendixsen et al., 2014,) cardiac function (Krustrup et al., 2014,) blood pressure, BMI, body composition (Ørntoft et al., 2016) and bone health (Larsen, Nielsen, Helge, et al., 2018) in children aged 8–12. However, a meta-analysis by Neil-Sztramko et al. (2021) found little to no differences in physical fitness, no differences in CRF and no differences in BMI in the included studies investigating school-based programmes for adolescents (Neil-Sztramko et al. 2021). These results emphasise the need for more high-quality randomised trials to identify which specific programmes are effective in eliciting beneficial changes in fitness and health indicators in the school environment. In their 2022 review Duncombe et al. supported the effectiveness of school-based high intensity interval training interventions on CRF, compared to non-exercise controls, but underlined that there need to be a specific focus on student enjoyment in the development of the interventions (Duncombe et al., 2022).

The FIT FIRST Teen (FFT) is a novel concept using high intensity training based on the sports the pupils can engage with in their leisure time, with a special focus on high levels of involvement and fun for all regardless of their individual starting point. The concept is developed in collaboration between researchers from the university, youth development consultants from several Danish sports federations and the Danish elite sports organisation Team Danmark. It targets the eldest pupils in Danish schools and aligns with the new Danish national PA guidelines for youth that emphasises the importance of high intensity PA and strength training (Sundhedsstyrelsen, 2023). No study has yet investigated the effects of a school-based, high intensity training programme on the health of Danish pupils aged 12–15. Given that they are shown to be the least active, when compared to younger pupils, it is both reasonable and important to investigate such a programme targeting this specific age-group. The aim of this study is to evaluate the effects of a 10-week school-based intervention with thrice weekly 40-minute FFT sessions on cardiorespiratory fitness, as well as several secondary outcomes (resting blood pressure and heart rate,

standing long jump, single leg balance and body composition) in 12–15-year-olds in Danish schools.

Methods

Study design

The study is a non-blinded, cluster-randomised controlled trial. Recruiting took place in the first half of 2022 and was done via LinkedIn posts and advertising in the Danish Sports Confederations newsletter. The study was not set up to be an efficacy trial and hence a priori power calculations were not performed. The number of intervention schools was chosen to secure decent representation of small/large, rural/urban schools and cover a large geographic area. Schools that were able and willing to participate were included. Hereafter, the schools were cluster-randomised in a c2:1 (INT(FFT):CON) ratio using an online randomisation software, stratifying by firstly rural/urban location, and thereafter by number of students at each school. The study was cluster-randomised at school level as it would not be feasible to randomise at student level and further to avoid potential crossover effects from one class to another at the same school. The c2:1 ratio was chosen, so it would be possible to perform subgroup analysis within the intervention group. In August, following the randomisation, the teachers from the intervention schools participated in a 1-day teachers training course. Pre-testing was conducted in August/September 2022, followed by a 10-week study period where the intervention schools performed three weekly FFT lessons and the control schools continued their usual physical education (PE) practice of one PE session per week. After 10 weeks of intervention or usual practice, the post-testing was conducted in November/December 2022.

The study is a part of the 'FIT FIRST for all'-project and was carried out following the Declaration of Helsinki guidelines. An inquiry was made with the Health Research Ethics committee of the Southern Region of Denmark which waived our obligation to report to them, meaning that they granted us with an ethics waiver (O'Rourke et al., 2022) (S-20210099). We were informed by the committee that written informed consent was not required in this type of study, but that we were obliged to inform the students and their legal guardians regarding the study procedures. Therefore, legal guardians of the participants received written information via the schools' internal communication platforms prior to the test days; further oral information was given to the students on the test days. Both children and parents were informed of the option to withdraw from participation in the trial at any point before or during the test and intervention period, as well as the possibility to have their data removed from analysis afterwards. The trial is registered in the ISRCTN Registry: ISRCTN76457599; <http://www.isrctn.com/ISRCTN76457599>.

Participants

Out of 1536 eligible pupils, a total of 1,417 pupils aged 12–15 from 15 Danish schools (four in large cities and 11 in rural areas) with representation from each of the five Danish regions participated in the study: FFT; $n = 994$ (11 schools, 6th grade (7

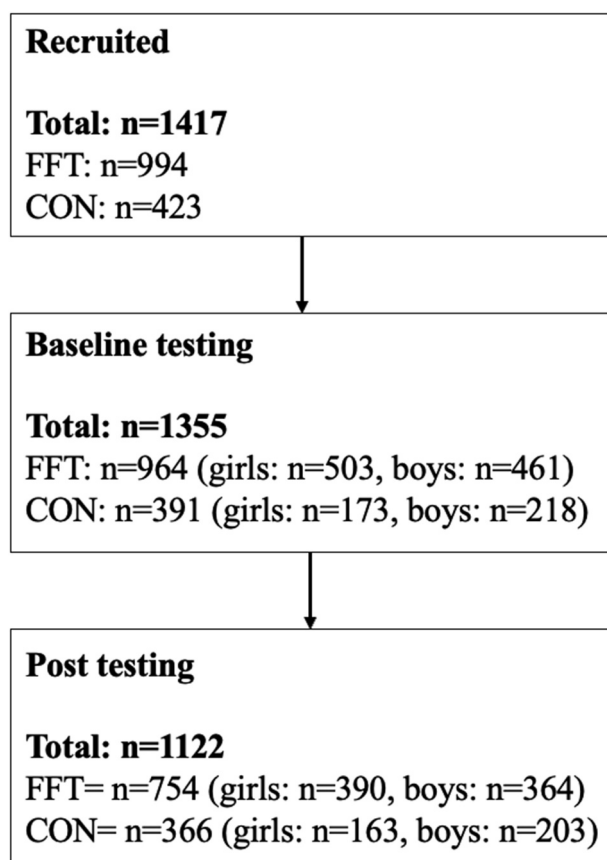


Figure 1. Participant flow chart.

classes), 7th grade (17 classes), 8th grade (15 classes), 9th grade (12 classes), CON; $n = 423$ (4 schools), 7th grade (5 classes), 8th grade (10 classes), 9th grade (5 classes). A full overview of participation can be found in the study flowchart (Figure 1).

Intervention

The FFT intervention consisted of three weekly 40-minute sessions of sports-related training for 10 weeks. All training sessions were carried out within each schools' sports facilities during normal school hours by teachers who attended a FFT teachers training course organised by the university. Teachers had full autonomy in scheduling the FIT FIRST sessions but were encouraged to perform the sessions Monday, Wednesday and Friday if possible. One of the weekly sessions was conducted within their regular PE lesson and two on different occasions. The teachers could choose freely between 63 lesson plans from 17 widely recognised leisure time sports (Figure 2). Each of the 63 FFT lessons has been developed in collaboration between researchers at the university, The Danish Sports Confederation (DIF) and Team Denmark (the Danish national elite sports organisation), along with consultants from each of the 17 participating sports federations. All lessons are developed to elicit an average heart rate (HR) of 75% of individual maximal HR, with at least 10% being above 90% max HR and containing elements of sprinting, strength

Sports in the FIT FIRST Teen manual
Auto mobile sports
Badminton
Basketball
Flag football
Football
Team handball
Judo
Ju-Jitsu
Kickboxing
Running (athletics, triathlon, orienteering)
Canoe and kayak
Rugby
Powerlifting
Volleyball

Figure 2. Sports in the FIT FIRST teen manual.

training and bone impact. The lessons have been tested on similarly aged pupils with the use of Polar Pro monitors (HR accelerometry, and GPS) to ensure that the lessons can elicit the intended stimulus. This was done as part of a development project, not yet published in the scientific literature (Aggestrup et al., 2022). Each sport was modified to consist mostly of small-sided games (3v3, 4v4) played interval style (i.e., 3 minutes of play and 1 minute of rest repeated 3–4 times), relays in groups of 2–4 students, partner exercises and active rest periods, as well as an overall decreased focus on complex sports specific techniques and rules, and an increased focus on highest possible level of MVPA in the 40 minutes. The sessions were designed with no or little equipment demands. Furthermore, most sessions were designed with the possibility to be conducted both inside in a gymnasium or outdoors on grass or paved areas, making it easier to schedule and perform the lessons even in schools with limited availability of a gymnasium. Three lessons translated into English can be found in the supplementary material (Sup.mat. A) and an updated version of the full manual in the original language is available at <https://www.dif.dk/raadgivning-og-stoette/mere-idraet-i-folkeskolen/fit-first>.

Teachers training course

The teachers' training course consisted of a presentation of the scientific background for the intervention by one of the primary investigators, followed by a practical session with five different sports. Firstly, examples were offered of the main principles of the programme with exercises from the manual from three sports, i.e., an 11v11 football game, followed by short 3v3 games, an athletics relay exercise and a high intensity partner-

exercise with taekwondo techniques. These were taught by researchers from the group. Secondly, two full sessions from two different sports followed, performed exactly as described in the manual, and were taught by coaches from the particular federations. After each sport there was time for reflection and discussion about pedagogical considerations of the elements. The training course concluded with a group talk about implementation at each school, addressing ideas and concerns from the teachers.

Measurements

The testing was done at the schools during school hours by researchers or students from the university. Testers were required to participate in supervised one on one training with experienced researchers, before being allowed to test independently. Before commencing the testing, a standardized introduction was given by the test leader, consisting of a description of each test, the test day flow and a reminder of their right to withdraw from testing at any point. Following this, any questions were addressed. Testing was performed at the local facilities of each school, starting at 8am, one class at a time, with classes in the same order for pre and post testing. The tests were conducted in the same order at pre- and posttest and consisted of individual measurement of height and body composition, resting systolic (SBP) and diastolic (DBP) blood pressure and resting heart rate (RHR), and single leg balance. Hereafter followed a 15-minute group-based standardised warm up routine. The warmup was a shortened version of the FIFA 11+ warm up routine (Soligard et al., 2008). It consisted firstly of running in pairs on a course with five pairs of flat cones approximately 5 m apart and with 4 m distance between each pair: Two rounds of forward running with sidesteps towards the middle, circling one's partner and back at each pair of cones, then two rounds of running two cones forward, one cone back until the end of the course. Secondly, 2 × 15 second plank holds and finally three standing long jumps. Directly hereafter all students did the standing long jump test one by one, immediately followed by a collective Yo-Yo Intermittent Recovery level 1 Children's test (Yo-Yo IRT1C) test.

Anthropometrics

Each participant's height was measured in centimeters barefoot one time (Tanita, Leicester Height Measure Mk II). Likewise, body composition was measured once with the participant still barefoot and in light clothing (InBody270, Chungcheongnam-do 331-824, South Korea) (Larsen et al., 2021). Body mass and muscle mass were reported in kgs, while fat mass was reported in percentage.

Leisure time sports club participation

During the InBody measurement each participant was asked about sports participation in the following manner: 'Do you currently participate in any leisure time club-based sports?' if yes: 'Which sport(s)?'. All answers were noted by the tester.

Resting heart rate and blood pressure

Resting HR (bpm), SBP and DBP (mmHg) was recorded three times with an automatic BP-monitor (M6 hEM-7322 U-E; Omron, Hoofddorp, The Netherlands) (Topouchian et al., 2014) directly on the skin on the upper left arm after 8 minutes of rest in a dark, quiet room in a supine position on mats. The average of the two lowest measurements were included in the analysis and mean arterial pressure (MAP) was calculated as $1/3 \text{ SBP} + 2/3 \text{ DBP}$.

Stork balance test

Single leg balance was measured with the Stork Balance Test (Johnson & Nelson, 1969). The test was performed without footwear and the participants were instructed to stand on the toes of their left foot, holding the right foot to the knee of the left leg and holding the hands on the hips. Each participant had three attempts on the left foot, followed by three attempts on the right foot. The tester was watching from the side, timing with a stopwatch. The time was stopped whenever the participant broke the starting position and the result in seconds was noted. The best of the six attempts was included in the analysis.

Standing long jump test

Following the individual tests, the participants went through a standardised warm up routine consisting of running, jumping, change of direction and strength exercises. After the warmup, the participants did a paused standing long jump test (Ashby & Heegaard, 2002; Dobbs et al., 2015) either barefoot or wearing shoes. The participants lowered themselves into a quarter squat, paused for 2 seconds to eliminate stretch-shortening of the quadriceps, and on command took off with their feet together, hands on their hips. The length of the jump was measured in centimetres from the starting line to the heel of the foot furthest back. Each participant had two jumps, of which the longest jump was included in the analysis.

Yo-yo intermittent recovery level 1 Children's test

Cardiovascular fitness was evaluated using the Yo-Yo Intermittent Recovery level 1 test for children (Ahler et al., 2012; Bendiksen et al., 2013, 2014; Póvoas et al., 2016). A course with a 16 m long running space, and a 4 m recovery space behind the start/finish line was set up in the gym or sports hall. The test consists of repeated 2 × 16 m shuttle runs at increasing speed, interspersed with 10-second recovery periods between each shuttle run, until exhaustion. The test was conducted collectively, with at least 1 m of running space for each participant. The participants had two trial runs before starting the test. Tempo was dictated on speakers by the audio recording for the original Yo-Yo IR1 test (Bangsbo et al., 2008). Testers and teachers were placed by the start/finish line and the turning point to ensure that the participants reached the points on time. A warning was given if the participant was not able to reach the finish line within the timeframe, started their run before the signal or ran short of the turning point. The test stopped for the individual when they were given their second warning. Their level was hereafter noted by the

test leader and in the following analysis, the total distance in metres was calculated from the levels.

Statistical analysis

Statistical analyses were performed in R Studio (Version 2024.12.0 + 467, Posit Software, PBC) All data are presented as mean $\pm$ SE unless stated otherwise. The effect of the intervention on the outcome variables was tested with multi-level linear mixed models (MLM) using the lmer function from the 'lme4' package in R studio (Bates et al., 2015) with group as the independent variable. Sex, and age, height, sports participation status at baseline, as well as the baseline value of the outcome variable were added as covariates. The model accounted for the hierarchical structure of the data by clustering at class level, which was nested within the school level. For SBP and muscle mass, the inclusion of both random effects resulted in singular fits, suggesting insufficient variability in the random effects. In these cases, the model was rerun with each level removed, and the results were consistent. As a result, the model was simplified by removing the school level for both outcomes. Additionally, to explore any subgroup differences, for each variable, the FFT and CON group were divided into tertiles, and the MLM was fitted to compare only the tertiles with the poorest starting point. The highest tertile was used for SBP, DBP, MAP, RHR, body mass, BMI and fat percentage. The lowest tertile was used for YYIR1C, standing long jump, stork balance test, muscle mass and muscle mass percentage. For the subgroup analyses of SBP, muscle mass, muscle percentage and fat percentage, the inclusion of both random effects resulted in singular fits. The model was rerun with each level removed, and the results were consistent. The model was simplified by removing school for the affected outcomes. For DBP and MAP, the model returned singular fits at both the class and school levels, indicating insufficient variability in the random effects at both levels. The model was rerun with the removal of one level at a time, but singular fits persisted. Consequently, both random effects were removed to simplify the model, as the results were consistent without them. Cohen's d was calculated for significant results, and the following scale of magnitude was used for its interpretation: trivial: $d < 0.20$; small: $0.20 < d < 0.49$; moderate: $0.50 < d < 0.79$; large: $0.80 < d < 1.19$; very large: $1.20 < d < 1.99$; huge: $d > 2.00$ (Cohen, 2013). For all analyses, results with a $p < 0.05$ were considered statistically significant.

To assess potential bias due to attrition, a comparison of baseline characteristics of participants completing both pre-tests and posttests to participants who were lost to follow up was completed using simple t-tests and Chi (Posadzki et al., 2020) tests. A significant difference was found in LTSCP (X^2 (1, $N = 1125$) = 6.5893, $p = 0.010$). The MLM accounts for missing data, and further, this variable is included as a covariate in the models and therefore any potential bias due to this difference is accounted for in the analysis. The results of the analysis can be found in the supplementary material (Sup. mat. B). The sample size varies for each outcome measure, as participation in tests was completely voluntary. Sample sizes for each test are included in Tables 1-4.

Results

The following sections are based on the adjusted results. For transparency reasons, and following relevant recommendations, Tables 1-4 can be found in the supplementary material without any adjustment other than clustering (Sup. Mat. C). One thousand three hundred and fifty-five pupils took part in the pre-intervention testing. The sample consisted of 51.1% girls, had a mean age of 13.6(0.0) (mean (SE)) years and a mean height of 166.4 (0.3)cm. About, 63.3% reported being active in club-based leisure time sports.

Blood pressure and resting heart rate

Table 1 presents the raw means (SE) for blood pressure and resting heart rate for baseline and posttests, along with the results of the MLM (group effect). The group effect analysis showed a statistically significant small difference in RHR ($d = 0.29$, 95% CI: 0.07 to 0.52, $p = 0.039$) in favour of the intervention. No significant differences between the intervention group and the control group on any of the remaining cardiovascular outcomes (SBP: $p = 0.485$, DBP: $p = 0.623$, MAP: $p = 0.800$).

Physical fitness

Table 2 presents the raw means (SE) for YYIR1C, standing long jump and stork balance for baseline and posttests, along with the results of the MLM (group effect). The group effect analysis showed no significant differences on either YYIR1C ($p = 0.080$), standing long jump ($p = 0.286$) or stork balance ($p = 0.750$).

Table 1. Cardiovascular factors before (pre) and after (post) the 10-week study period for the intervention group (FFT) and the control group (CON).

	FFT		Control (CON)		FFT vs. CON		
	Pre	Post	Pre	Post	Estimate	95% CIs	p-value
Systolic blood pressure (mmHg)	103 (0.3) n = 920	105 (0.3) n = 707	105 (0.5) n = 380	106 (0.4) n = 331	0.2 (0.3)	−0.4; 0.8	0.485
Diastolic blood pressure (mmHg)	62 (0.2) n = 920	63 (0.2) n = 707	62 (0.4) n = 380	63 (0.3) n = 331	−0.2 (0.3)	−0.7; 0.4	0.623
Mean arterial pressure (mmHg)	76 (0.2) n = 920	77 (0.2) n = 707	76 (0.3) n = 380	77 (0.3) n = 331	−0.1 (0.3)	−0.7; 0.5	0.800
Resting heart rate (bpm)	72 (0.3) n = 920	70 (0.3) n = 707	69 (0.5) n = 380	71 (0.5) n = 331	−1.7 (0.7)*	−3.1; −0.3	0.039

Raw means (SE).

*indicates a significant between-group difference ($p < 0.05$).

FFT vs CON: Fixed effect estimate of group, adjusted for sex, and age, height and LTSCP status and outcome variable at baseline.

Table 2. Physical fitness before (pre) and after (post) the 10-week study period for the intervention group (FFT) and the control group (CON).

	FFT <i>n</i> = 1085		Control (CON) <i>n</i> = 451		FFT vs. CON		
	Pre	Post	Pre	Post	Estimate	95% CIs	p-value
Yo-Yo IR1C distance (m)	670 (15.0) <i>n</i> = 884	689 (15.3) <i>n</i> = 672	777 (26.1) <i>n</i> = 354	868 (28.6) <i>n</i> = 300	−61.3 (28.5)	−117.2; −5.4	0.080
Standing long jump (cm)	128.7 (0.8) <i>n</i> = 901	130.4 (0.8) <i>n</i> = 680	134.7 (1.2) <i>n</i> = 336	136.3 (1.2) <i>n</i> = 299	−1.9 (1.6)	−5.0; 1.2	0.286
Stork balance stand (sec)	7.6 (0.2) <i>n</i> = 923	7.4 (0.2) <i>n</i> = 733	7.6 (0.4) <i>n</i> = 342	7.4 (0.3) <i>n</i> = 357	0.1 (0.4)	−0.7; 0.9	0.750

Raw means (SE).

*indicates a significant between-group difference ($p < 0.05$).

FFT vs CON: Fixed effect estimate of group, adjusted for sex, and age, height and LTSCP status and outcome variable at baseline.

Table 3. Body composition before (pre) and after (post) the 10-week study period for the intervention group (FFT) and the control group (CON).

	FFT <i>n</i> = 1085		Control (CON) <i>n</i> = 451		FFT vs. CON		
	Pre	Post	Pre	Post	Estimate	95% CIs	p-value
Body Mass Index	57.8 (0.4) <i>n</i> = 912	58.9 (0.4) <i>n</i> = 707	58.6 (0.6) <i>n</i> = 378	58.8 (0.6) <i>n</i> = 348	−0.0 (0.0)	−0.1; 0.1	0.981
Body Mass Index	20.9 (0.1) <i>n</i> = 912	21.0 (0.1) <i>n</i> = 707	20.7 (0.2) <i>n</i> = 378	20.6 (0.2) <i>n</i> = 348	−0.0 (0.0)	−0.1; 0.1	0.981
Muscle mass (kg)	24.3 (0.2) <i>n</i> = 906	24.5 (0.2) <i>n</i> = 705	15.6 (0.3) <i>n</i> = 377	25.4 (0.3) <i>n</i> = 345	1.1 (0.1)	0.9; 1.3	0.089
Muscle mass (%)	42.6 (0.2) <i>n</i> = 906	42.0 (0.2) <i>n</i> = 705	43.8 (0.3) <i>n</i> = 377	43.5 (0.3) <i>n</i> = 345	−0.0 (0.1)	−0.2; 0.3	0.764
Fat percentage (%)	22.1 (0.3) <i>n</i> = 906	23.1 (0.3) <i>n</i> = 705	20.1 (0.4) <i>n</i> = 377	20.7 (0.4) <i>n</i> = 345	−0.1 (0.1)	−0.1; 0.3	0.469

Raw means (SE).

*indicates a significant between-group difference ($p < 0.05$).

FFT vs CON: Fixed effect estimate of group, adjusted for sex, and age, height and LTSCP status and outcome variable at baseline.

Table 4. Subgroup analysis: before (pre) and after (post) the 10-week study period for the third with the poorest starting point in the intervention group (FFT) and the control group (CON).

	FFT		Control (CON)		FFT vs. CON		
	Pre	Post	Pre	Post	Estimate	95% CIs	p-value
Systolic blood pressure (mmHg)	113 (0.3) <i>n</i> = 306	112 (0.4) <i>n</i> = 306	115 (0.4) <i>n</i> = 126	112 (0.8) <i>n</i> = 126	0.6 (0.5)	−0.4; 1.6	0.171
Diastolic blood pressure (mmHg)	70 (0.2) <i>n</i> = 306	67 (0.3) <i>n</i> = 306	70 (0.4) <i>n</i> = 126	68 (0.6) <i>n</i> = 126	−0.2 (0.4)	−1.0; 0.6	0.558
Mean arterial pressure (mmHg)	83 (0.2) <i>n</i> = 306	81 (0.3) <i>n</i> = 306	84 (0.4) <i>n</i> = 126	82 (0.5) <i>n</i> = 126	−0.0 (0.3)	−0.6; 0.6	0.970
Resting heart rate (bpm)	84 (0.4) <i>n</i> = 306	78 (0.6) <i>n</i> = 306	81 (0.6) <i>n</i> = 126	79 (0.9) <i>n</i> = 126	−1.5 (0.7)	−2.8; −0.1	0.080
Yo-Yo IR1C distance (m)	257 (4.0) <i>n</i> = 295	320 (7.7) <i>n</i> = 295	304 (7.1) <i>n</i> = 118	434 (21.1) <i>n</i> = 118	−35.0 (18.9)	−72.0; 2.0	0.088
Standing long jump (cm)	102.5 (0.8) <i>n</i> = 301	107.0 (0.9) <i>n</i> = 301	108.9 (1.2) <i>n</i> = 112	114.0 (1.6) <i>n</i> = 112	−2.1 (1.5)	−5.0; 0.8	0.192
Stork balance stand (sec)	2.8 (0.0) <i>n</i> = 308	4.2 (0.2) <i>n</i> = 308	2.8 (0.1) <i>n</i> = 114	4.0 (0.2) <i>n</i> = 114	0.1 (0.3)	−0.5; 0.7	0.728
Body mass (kg)	73.0 (0.7) <i>n</i> = 304	73.3 (0.7) <i>n</i> = 304	72.7 (0.9) <i>n</i> = 126	72.1 (0.9) <i>n</i> = 126	−0.0 (0.2)	−0.4; 0.4	0.945
Body Mass Index	25.5 (0.2) <i>n</i> = 304	25.3 (0.2) <i>n</i> = 304	24.8 (0.3) <i>n</i> = 126	24.6 (0.3) <i>n</i> = 126	−0.0 (0.1)	−0.2; 0.1	0.532
Muscle mass (kg)	18.9 (0.1) <i>n</i> = 302	19.2 (0.1) <i>n</i> = 302	19.9 (0.1) <i>n</i> = 126	20.0 (0.2) <i>n</i> = 126	0.1 (0.1)	−0.1; 0.3	0.239
Muscle mass (%)	36.2 (0.2) <i>n</i> = 302	36.1 (0.2) <i>n</i> = 302	37.4 (0.4) <i>n</i> = 126	37.5 (0.3) <i>n</i> = 126	−0.2 (0.2)	−0.6; 0.2	0.190
Fat percentage (%)	33.5 (0.3) <i>n</i> = 302	33.7 (0.3) <i>n</i> = 302	30.9 (0.5) <i>n</i> = 125	31.1 (0.5) <i>n</i> = 125	−0.2 (0.1)	−0.4; −0.0	0.267

Raw means (SE).

*indicates a significant between-group difference ($p < 0.05$).

FFT vs CON: Fixed effect estimate of group, adjusted for sex, and age, height and LTSCP status and outcome variable at baseline.

Body composition

Table 3 presents the raw means (SE) for body mass, BMI, absolute and relative muscle mass, as well as body fat percentage for baseline and posttests, along with the results of the MLM (group effect). The group effect analysis showed no significant differences on any of the body composition outcome variables (Body mass: $p=0.322$, BMI: $p=0.981$, muscle mass: $p=0.089$, muscle percentage: $p=0.764$, fat percentage: $p=0.469$).

Sub-group analysis

Table 4 shows the raw means (SE) for all outcome variables at baseline and posttest for participants in the least favourable tertile at baseline, along with the results of the MLM (group effect). No significant differences were found between groups in any outcomes.

Discussion

The present study evaluated the effect of a thrice-weekly 10-wk FIT FIRST Teen intervention (FFT) on body composition and markers of fitness in 12–15 years-old Danish adolescents. The main finding of the study was that no significant effect of the intervention was found in YYIR1C test performance and the majority of the secondary outcomes. However, there was a significant small effect of the intervention on RHR, which is also related to the cardiovascular fitness level (Farah et al., 2015).

The lack of significant findings in the present study aligns with the conclusions of Neil-Sztramko et al., 2021 who found little to no effect on CRF, physical fitness and BMI of school-based PA interventions for the average adolescent population (Neil-Sztramko et al., 2021) which is the target population in this study, that matches Danish norms (Wohlfahrt-Veje et al., 2014). However, when reviewing the literature of high intensity interval training interventions specifically, Duncombe et al. concluded that this type of intervention effectively can improve CRF (Duncombe et al., 2022) compared to non-active controls. In their study running the FIT FIRST programme on an entire school (1st - 9th grade) in the Faroe Islands, Olsen et al. found the programme to significantly improve CRF, agility and body composition in the FIT FIRST group across all ages, compared to a control school doing usual practice PE (Olsen et al., 2024). This suggests that the programme does have the potential to be effective in a Nordic school setting, but that there is a need to explore the qualitative evaluations of the present trial to identify the challenges faced by teachers when employing the programme in Danish schools.

Previous studies of school-based PA interventions have shown favourable effects on CRF in both younger and similarly aged participants. Ardoy et al. (Ardoy et al., 2011) found a difference in change of 5 mL/min/kg in 12–14-yrs-olds between a control group performing two normal PE sessions per week and an intervention group taking part in four high intensity PE sessions per week for 16 weeks, and Bendiksen et al. (Bendiksen et al., 2014) found a 22% significant increase in YYIR1C performance in 8–9-yrs-old Danish pupils after 6 weeks bi-weekly small-sided games, compared to a control

group. However, differing from the present study, the training in the study by Bendiksen et al. was organised and controlled by sports science educated research staff, and the intensity was likely higher during the training session, as they reported as much as 42% of the training time above 80% of individual HR-max. Further, studies of longer duration in Danish children have effectively improved different health variables with comparable interventions. Skoradal et al. (Skoradal et al., 2018) and Ørntoft et al., 2016) have shown improvements in cardiovascular measures, body composition, and physical fitness with 2 × 45 minutes of high intensity ball games in the 11-week '11 for Health' programme in Danish and Faroese 10–12-yrs-olds, while (Larsen, Nielsen, Helge, et al., 2018) found increased bone mineral density (BMD), balance, and long jump performance after a 10 month FIT FIRST trial with 3 × 40 minutes small-sided ball games and strength training in 8–10-yrs-olds. Further in 2020, (Larsen et al., 2020) found that 5 × 12 minutes per week of high intensity small-sided ball games or interval running improved DBP and selected echocardiographic measures in 10 months in 8–10-year-olds.

The FFT group had a decrease in RHR compared to the CON group ($d=0.29$, 95% CI: 0.07 to 0.52, $p=0.039$). No between-group differences were found on the remaining cardiovascular parameters. This is in line with a study by Krstrup et al., showing no detectable changes on resting BP on 9–10-years-old after a 10-week intervention period with thrice-weekly football training (Krstrup et al., 2014). However, (Larsen, Nielsen, Madsen, et al., 2018) showed a decrease in diastolic BP after 10 months of thrice-weekly small-sided games and circuit strength training in 8–10-years-olds. This suggests that a longer study period is needed for interventions like these to induce detectable changes on the measures in question. As lower resting HR is associated with a decreased risk of CVD and CVD risk factor accumulation (Saxena et al., 2013, Palatini et al., 2004, Ortega et al., 2008), the differences observed in the present study are promising in terms of using the present concept as health prevention, despite the small effect size, since it was only a 10 week intervention and qualitative data suggest that an implementation throughout the full school period is possible, as teachers reported delivering all three weekly sessions with a maximum of two cancellations across the 10-week period due to other class obligations (Nejst Larsen, 2025).

The sub-group analysis exploring potential changes in the participants with the poorest starting point in each outcome variable did not show any different results than the main analysis, thereby establishing that the non-significant results of the intervention on the full sample were not simply due to differentiated results across the spectrum of baseline fitness.

This study is the first of its kind in Danish adolescents. As shown above, there are multiple examples of how similar interventions in younger groups have proven very effective in eliciting beneficial health effects in as little as 6 weeks, however there are several factors when working with the adolescent population, that inevitably will challenge a study like this one. First of all, the adolescent population is generally less physically active than the children (Sundhedsstyrelsen, 2023b; Toftager et al., 2023). According to the teachers involved in the project, this proved to be challenging in several ways. Some pupils

showed a general disinterest in being physically active, while a more widely spread challenge was the pupils not feeling comfortable with working at high intensities and getting sweaty, out of breath and red faced among each other (Nejst Larsen, 2025). Secondly, reports from the Danish Research and Implementation Centre for Human Movement and Learning (FIIBL) and Dansk Skoleidræt (The Danish physical education organisation) show that teachers experience challenges with having the pupils shower together after PE and the challenges seem to increase with increasing age (Guldager et al., 2023; Oxford Research, 2017). In the latest report from FIIBL regarding physical education in 2022, 42% of the responding teachers experienced challenges with showering for the youngest pupils (1st - 3rd grade), 65% experienced challenges for the 4th-6th grade pupils and 79% experienced challenges for the 7th - 9th grade pupils (Guldager et al., 2023). This is likely to impact the desire and will to reach high intensities that will induce sweat and thereby a need for showering. Based on this we now recommend placing the teaching at the end of the school day, so that the pupils can choose to shower at the school afterwards or at home (Nejst Larsen, 2025). Furthermore, a relatively recent introduction of an exam in PE after 9th grade, could lead to focus on the theoretical parts of the curriculum, decrease the PA levels (Guldager et al., 2023). In the present study there was no intensity monitoring, but a trial using the same programme found the intensities during two selected sessions almost met the criteria of an average heart rate of 75%-HRmax, which strengthens the assumption that the programme is effective in eliciting high intensities (Olsen et al., 2024).

Strengths and limitations

The present study is the first study investigating the high intensity school-based intervention programme FIT FIRST Teen for Danish adolescents. The strengths of the study include the cluster-randomised controlled design with a large study population, with representation from both rural and urban areas in all five regions of the country. However, it is important to consider that the findings might not be fully representative of the entire population due to the convenience sampling method, as the volunteering schools may have unique characteristics that differ from broader population. Limitations of the study includes the relatively short study period of 10 weeks, no fidelity checks, intensity monitoring during the intervention period, lack of assessment of the PA levels before and during the intervention by accelerometry or survey, and no dietary control. Attendance measures in the form of logbooks were set in place, however, due to limited time, the teachers prioritised getting as much PA time as possible, deprioritizing taking attendance. This resulted in insufficient logbooks, and ultimately useless attendance records. Further, the use of field tests with lower validity and reliability compared to golden standard tests are also to be taken into account when interpreting the results, since the present study might be underpowered to detect all potential differences. In future studies it should be of high priority to measure heart rate during the YYIR1C test to obtain reference maximum heart rates and assess the maximality of the test, as well as conduct fidelity

checks with heart rate measurements during the intervention period to assess the intensity of the intervention delivered.

Conclusion

In conclusion, the 10-week FIT FIRST Teen intervention did not improve Yo-Yo Intermittent Recovery 1 Children's test performance, nor any other physical fitness or body composition outcomes. It did have a significant positive effect on resting heart rate, suggesting that in-school, thrice-weekly, high intensity sports-based training can be used to improve the physical fitness of Danish adolescents, but the lack of positive effects on the other variables call for further development and long-term evaluation of the FIT FIRST Teen programme.

Perspectives

Physical activity (PA) habits established during the teen years tend to track into adulthood (Batista et al., 2019; Sundhedsstyrelsen, 2023b) and currently the trend is that adolescents are quitting organised leisure time sports and in general are less physically active (Rask et al., 2022; Toftager et al., 2023). Therefore, creating school-based PA programmes that are fun, involving and motivating for this age group is highly relevant to overcome the challenge of creating or maintaining good PA habits during the teen years as well as improving the overall health, decreasing the accumulation of risk factors for non-communicable diseases.

The findings from this short-term study, are aligned with previous studies, suggesting that school-based programmes like the FFT can positively influence cardiovascular health in adolescents. Future studies should examine whether more broad-spectrum effects will be seen with a longer study period and if well-being will follow the physical effects.

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Data availability statement

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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