JOURNAL OF Physical Activity & Health

# Outcomes of the Y-PATH randomised controlled trial: can a school based intervention improve fundamental movement skill proficiency in adolescent youth?



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| Journal: | *Journal of Physical Activity & Health* |
| Manuscript ID | JPAH.2016-0474.R2 |
| Manuscript Type: | Article |
| Keywords: | motor control, intervention study, adolescent, physical activity, physical education, motor behavior |

**Abstract**

*Background*. Multi-component school-based interventions are considered to be an effective method of improving fundamental movement skill (FMS) proficiency levels and physical activity (PA) among youth. This study aimed to evaluate if the Youth-Physical Activity Towards Health (Y-PATH) intervention can improve FMS proficiency in a randomised controlled trial among adolescents.

*Methods*. Participants were 482 adolescents aged 12-13 years from twenty schools. For one academic year, participants in ten schools received the Y-PATH intervention. The remaining ten schools received their regular weekly PE lessons. Fifteen FMS were assessed using validated tools, their PA was assessed using accelerometers, their height and weight and cardio-respiratory fitness was also recorded. Outcomes were assessed at baseline, post-intervention, and three months later at retention. Multilevel analysis were performed using MLwiN 2.35 software.

*Results*. Significant intervention effects across time were observed for Total Object Control ($p<.0001$, $\beta=2.04$, CI=1.16, 2.92) and Total Locomotor ($p<.0001$, $\beta=2.13$, CI=1.44, 2.82), with the greatest improvements evident for Total FMS score ($p<.0001$, $\beta=4.04$, CI=2.39, 5.69). The effects of the intervention were significant and positive for all children in the Intervention group regardless of gender, weight status, or PA level ($p=.03$ to $<.0001$).

*Conclusions*. Y-PATH has the potential to improve FMS proficiency among adolescents regardless of gender, weight status and activity levels.

**Introduction**

Fundamental movement skills (FMS) have been defined as basic observable patterns of movement [1]. There are three sub-tests of FMS which consist of locomotor skills (e.g. run, skip, hop), object control skills (e.g. catch, kick, strike) and stability (balance) [1]. Gallahue et al. [1] highlight that children have the developmental potential to master FMS by the age of six years, and all should have mastered them by the age of 10 in order to develop specialised movement skills that can later be applied to sports. FMS development during childhood can assist lifelong physical activity (PA) participation [1]. There is evidence among children that FMS, in particular locomotor skills, are positively correlated with PA [2]. Researchers agree that "cross-sectional evidence has demonstrated the importance of motor skill proficiency to PA participation" (p.253) [3]. However, it is difficult to determine the direction of this relationship. Results from various studies which examined the relationship between PA and FMS found that FMS proficiency is positively correlated with time spent participating in PA, and that targeting FMS proficiency development in children and adolescents may be significant in counteracting physical inactivity [4, 5, 6, 7]. It is also well known that adolescence is a period with a rapid decline in PA [8] which can contribute to the rising numbers of obese youth [9]. The established associations between FMS, Body Mass Index (BMI) and PA can be summarised by postulating that because adolescents may be non-proficient at performing FMS [10], they are less likely to be physically active [11] and show preferences for sedentary activities which may lead to an increase in BMI [12]. Therefore, during this key adolescent period it is important to focus on the development of factors correlated with PA such as FMS [13].

Lubans et al. [14] not only found a positive relationship between FMS competency and PA, and an inverse relationship between FMS competency and weight status, but also found strong evidence to support a positive relationship between FMS competency and cardio-respiratory fitness (CRF). Stodden, Langendorfer, and Roberton [15] discuss the relationship between FMS, PA and CRF and state that during adolescence FMS proficiency and high fitness levels allow individuals to persist and achieve success in activities therefore creating more opportunities to further develop these FMS.

It is also important when focusing on FMS to consider gender as a moderator. While research suggests both male and female adolescents achieve below expected age-related FMS proficiency levels, it also highlights that gender differences exist [6, 14, 16]. Results of studies assessing gender differences in FMS appear inconsistent with regard to locomotor and object control skills, however the majority of these studies report that males are significantly more proficient at FMS than females [3, 14, 16]. This suggests that while females are not only less active than males [17, 18], they also have lower FMS proficiency [3, 14, 16]. Considering the interplay between PA, BMI and FMS [12] it is important that the development of FMS includes all adolescent sub-groups most at risk (i.e. females, overweight/obese and the inactive).

There is a common misconception that FMS develop naturally through free play [19, 20] however it is known that they must be taught [21, 22]. Various studies support the fact that these FMS must be taught and practiced both in educational and free play settings [23, 24, 25]. Booth et al. [23] propose that it takes approximately 10 hours of teaching for an average child in the fundamental movement phase to become proficient at one FMS. As Robinson and Goodway [26] state, FMS must be learned, practiced and reinforced. Okely and Booth [23] advocate that primary school Physical Education (PE) programs should contain FMS as a key feature. This is the case in Ireland with the Irish Primary school PE curriculum which states that a "child's holistic development, stressing personal and social development, physical growth and motor development" should be a core focus while teaching primary school PE (p.9)[27]. In reality, however, this is not the case as according to O' Brien et al. [16] children are entering secondary schools lacking in basic FMS proficiency. A consequence of children being below the expected levels of FMS proficiency for their age [14, 28] may be an increased difficulty developing more advanced sports skills during adolescence [1], which may result in a decrease in participation in PA or sport [11]. It is logical therefore to suggest that although FMS may be present as a key feature in the primary school curriculum, in terms of actual teaching in a PE context, more focus is required. Strong et al. [29] acknowledge that there is less emphasis placed on the development of FMS during adolescence but argues that mastery of FMS and the development of more advanced skills are important during this time as they can contribute to maintenance of active lifestyles. Since adolescents are not at the required level of FMS proficiency to advance to sport specific skills [16, 24], it is crucial that interventions are developed to target this specific lack of motor skill proficiency among this age group as it can have a direct effect of PA participation [30].

Research suggests that adolescents should be developing sport specific skills but are not yet at the mastery level required for FMS [6, 16, 23, 24]. Booth et al. [23] and Mitchell et al. [24] found that for nine to 15 year olds and five-13 year olds mastery levels did not exceed 40 % for the FMS which were assessed.

There is a similar trend in Ireland as a study on PE indicated that fundamental over arm throwing amongst adolescent youth (15-16 years) was low [31]. A more recent study by O'

Brien et al. [16] assessed Irish 12-13 year olds on nine FMS. The findings state that 11% achieved mastery or near mastery on across all nine skills. Although the mastery levels for each skill may vary from country to country the proficiency levels remain consistently low. This evidence would suggest a need to improve FMS development among children and adolescents to ensure mastery in these basic skills prior to the advancement to the sport specific stage.

When targeting a group such as adolescents who are at a high risk of PA drop out [32], and are not at the required level of FMS proficiency, it is important to intervene while taking into account the needs of this population. Research suggests that multi-component school-based interventions not only see a rise in PA levels during school hours but can also increase PA levels outside of school time which is crucial to ensuring the desired long-term behavioural change and a knock-on effect on FMS development [33, 34]. In a review of recent publications results show that PA promotion in the school setting leads to an increase in school-based PA and is associated with an increase in out- of-school, and even more importantly, in overall PA [33]. The overall results highlighted that every single study with a PA outcome (n=16) reported a significant intervention effect in at least one domain of PA, in-school, out-of-school or overall [33]. There is also significant evidence highlighting the importance of implementing a whole school approach, family and wider community components in adolescent interventions as this is more effective than a specific curriculum change [35, 36]. A behavioural and community focus in PE and school-based interventions provides strong evidence as an effective strategy to improve PA and fitness among youth [37, 38, 39]. Youth-Physical Activity Towards Health (Y-PATH) is an example of one such intervention [13]. The Y-PATH intervention was designed in line with the Youth Physical Activity Promotion (YPAP) Model with a view to enabling youth to positively re-evaluate their predisposing factors 'Am I able' (e.g. self-efficacy) and reinforcing factors 'Is it worth it' (e.g. enjoyment, attitudes), while also addressing the enabling factors (e.g. skill level) that influence participation [13]. The YPAP model adopts a social-ecological framework acknowledging the input of various personal, social and environmental influences on physical activity. Similar to previous effective interventions [38, 40, 41], Y-PATH is a multi-component school-based intervention containing a family component which is implemented over the academic year (eight months). The purpose of Y-PATH is to increase PA levels of adolescent youth, through "enabling youth to positively re-evaluate their predisposing factors 'Am I able' (e.g. self-efficacy) and reinforcing factors 'Is it worth it' (e.g. enjoyment, attitudes), while also addressing the enabling factors (e.g. skill level) that influence participation" (p.8)[13]. In an exploratory trial of Y-PATH [35] involving 174 aged 12-14 years old boys and girls, the intervention group significantly increased daily moderate-vigorous PA (MVPA) by 7.2 minutes more than participants in the control group at the retention phase of the intervention [35]. The intervention and control groups both saw an improvement in FMS, however the improvement observed in the intervention group was significantly greater than the one in the control group [35]. The results of the Y-PATH exploratory trial suggest that it is an effective intervention to improve FMS proficiency, though to confirm their positive findings the authors cautioned for the need to evaluate the intervention with a larger sample in a randomised controlled trial.

It is evident that there is a lack of FMS proficiency among adolescents which may lead to difficulties in developing more advanced sport specific skills [1]. If this lack of FMS proficiency is disregarded, it may result in a reduction of adolescent participation in PA and sport [1]. Since these FMS must be taught [29] and do not naturally develop, it is essential that an effective intervention such as the Y-PATH program targeting FMS proficiency is implemented. Prior to long-term implementation it is essential that the Y-PATH intervention is subjected to a robust method of assessment [42]. The purpose of this study was to evaluate the efficacy of the Y-PATH intervention in improving adolescent FMS in a cluster randomised controlled trial and to determine whether the intervention had differential effects on gender, weight status and PA level sub-groups. The hypothesis of this study is that FMS proficiency levels of adolescents would improve as a result of participating in multi-component school-based Y-PATH intervention.

## Methods

*Procedures*

All mixed-gender second level schools in County Dublin, Ireland (n=104) were sent a letter inviting their participation in a cluster randomised controlled trial (RCT) of the Y-PATH intervention. A RCT is a type of scientific experiment which aims to reduce bias when testing a new treatment or intervention. The people participating in the trial are randomly allocated to either the group receiving the treatment/intervention under investigation or to a group receiving no treatment/intervention known as the control. Randomization minimises selection bias and the different comparison groups allow the researchers to determine any effects of the treatment when compared with the control group, while other variables are kept constant [43]. In this study, limited information was given on the intervention, due to potential contamination of the intervention and control groups, however information on testing requirements was provided as well as the main objectives of the intervention. On receipt of the expression of interest from 26 schools, another letter was sent to the PE teacher from each school requesting basic information to ensure the school satisfied the inclusion criteria: mixed-gender, qualified PE teacher, first year class groups (age 12–14) timetabled for a double PE class (minimum 70 minutes) each week. Once inclusion criteria were met, and principals and PE teachers consented to participate, one first year class per school, was randomly selected by the school principal for participation. Based on data from the Children's Sport Participation and PA study [28] which showed that only 12% of youth achieved the guideline for PA, a total of 18 schools (nine per arm), with an average of 27 participants per school, will provide at least 80% power at 5% level of significance (two-sided) to detect a difference of 20% (with an ICC of 0.1) in the proportion of children meeting the PA guidelines at six months. Allowing for attrition an additional two schools per arm with 27 students per school will be recruited; thus the study will involve 20 schools with approximately 27 students per school. Schools were pair-matched prior to data collection on the following criteria: socio-economic status (disadvantaged, non-disadvantaged and fee paying), school size (small 0-299 students, medium 300-599 students, large 600+ students), and facilities (school hall, size of hall, basketball courts, etc.). One school from each pair was then randomly allocated to the control group or the intervention group before baseline. Informed consent for participation was granted by each participant and their parent/guardian; all participants were free to withdraw from the study at any stage. Full ethical approval for this study was granted by Dublin City University research ethics committee (DCUREC/2010/081). Students only experience of PE was of primary school PE taught by a non-specialist teacher. PE teachers in the intervention schools received one day of in-service training for implementing the intervention prior to the beginning of the school year which was delivered by four members of the research team (all of which are qualified

PE teachers, two of which have completed PhD's and are experienced researchers in PE). The in-service training consisted of educating the PE teachers about the development of FMS, the assessment of FMS, the implementation of the PE lessons to focus on FMS. They were provided with many resources on the day including lesson plans and a DVD of sample lessons.

*Intervention*

The CONSORT guidelines [44] were followed for reporting the results of this study. The Y-PATH intervention is a multi-component school-based intervention which consists of four components [13]; 1) The student component: specific focus on health related activity and FMS in PE, 2) Parent/guardian component: parents and guardians are educated about the health benefit of PA, 3) Teacher component: all school staff participate in two workshops with the main objective to promote PA participation among staffs and students during school time, and 4) The website component: resources are made available online. Further detail on the Y-PATH intervention development and structure is given in [13]. See Figure 2 for an overview of the structure of Y-PATH.

*Data Collection*

Data were collected at three time points: baseline (September 2013), post-intervention (May 2014), and retention (September 2014). Between September and May the schools in the control group continued with regular PE once a week delivered by their PE teacher, while the intervention schools implemented the Y-PATH intervention in their PE lesson, and the Y-PATH programme more broadly throughout the school. Fifteen FMS were assessed during a regular PE class at the participants' school. The Test of Gross Motor Development-

2nd Edition (TGMD-2) [45] was used to assess 12 of these skills which were made up of six locomotor (run, hop, gallop, slide, leap and horizontal jump) and six object control skills (catch, kick, throw, dribble, strike and roll). The remaining three skills comprised of the skip, vertical jump which were assessed using the Test of Gross Motor Development (TGMD) [46] and the balance, which were assessed using the Victorian Fundamental Movement Skills Manual [47]. These skills were included as they were deemed relevant to the Irish sporting culture as demonstrated in O' Brien et al. [16]. The TGMD-2 displayed good concurrent validity with r=.63 for total FMS, r=.63 for locomtotoe skills and r=.41 for object control skills [45]. The correlation co-efficent for the test-restets reliability ranged from good to excellent (r=.84-r=.96) [45].

Consistent with the TGMD-2 protocol and to ensure accurate measurement of the FMS, trained researchers demonstrated each of the skills once. Participants received a brief description of each skill. They then completed one practice go and two trials of each skill with no feedback given at any stage. All trials were accurately videoed with full body movement in view. These videos were then labelled and saved for later assessment. Prior to data analysis researchers were trained to assess these videos accurately with a minimum of 95% inter-rater and intra-rater reliability achieved by researchers. They then completed assessment of the skills as per TGMD-2 guidelines scoring a “1” if the component of the skills is present and a “0” if it is absent. For each FMS, the two test trials were added together to get the total for each skill score. Then all locomotor skills were totalled (maximum possible score=66), all object control skills (maximum possible score=48) were totalled and an overall FMS score was obtained (maximum possible score=124).

Body mass (kg) and height (m) were directly measured using a SECA Leicester Portable Height Measure and a SECA calibrated heavy-duty scale. Weight status was categorised into normal weight (NW) and overweight/obese (OWOB) based on gender specific BMI cut points [48]. Participants were asked to wear an Actigraph GT1M, GT3X, or GT3X+ accelerometer (Actigraph LLC, Pensacola, FL) for a period of nine days on their right hip. Vertical accelerations were used as these are comparable between the three models of Actigraph [49]. Accelerometers were set to record using 10-sec epochs. The first and last day of accelerometer data were omitted from analysis to allow for subject reactivity [50]. The minimum number of valid days was three weekdays and one weekend day [35, 51]. In line with other studies, a day was deemed valid (and therefore included in the analysis) if there was a minimum of 10 hours recorded wear time per day [35, 51]. Monitor non-wear was defined as ≥20 consecutive minutes of zero counts [35, 51]. Counts below zero and above 15,000 were excluded due to biological plausibility [35, 50]. The mean daily minutes spent in MVPA was estimated using validated cut points for adolescents in this age group: MVPA ≥2296 counts/min [52]. PA level was categorised into two groups; <=60min moderate-vigorous PA per day were deemed inactive and >=60min MVPA per day were deemed active.

The Queens College three-minute step test was administered to calculate an estimate of CRF using estimated $VO_{2max}$. A protocol as per McArdle, Katch, Pechar, Jacobson, and Ruck was followed and it is deemed reliable and valid for use for estimating CRF in young people [53]. After a 20 second familiarisation period, and once all participants were comfortable with the process, the three-minute trial began whereby each participant continuously stepped for three minutes up and down a pre-set height of 41cm (bench/steps) to a metronome. Cadence was set at 22 steps per minute for females and at 24 steps per minute for males.

Post-trial, a trained researcher was given five seconds to find the pulse in the participants' right wrist. Once researchers had the pulse, it was counted for a 15 second period post-exercise. This was converted to beats per minute (bpm) and subsequently used to calculate $VO_{2max}$ using the following gender specific formulae: male $VO_{2max}$ (ml/kg/min) =111.33 - (0.42 x heart rate (bpm)); female $VO_{2max}$ (ml/kg/min) =65.81 - (0.1847 x heart rate (bpm)) as per McArdle et al. [53].

*Data Analysis*

Multilevel linear regression analyses examined the effect of the Y-PATH intervention on the three FMS outcome measures: Total Object Control score, Total Locomotor score, and Total FMS score. Separate analyses were conducted for each outcome measure. A three level multilevel structure with random intercepts was used, where timing of the follow-up measurement (post-intervention and retention; Level one), pupils (Level two), and schools (Level three) served as the grouping variables. This structure accounted for the measures taken at different time points being nested in pupils, who were nested in schools. To estimate the impact of the intervention on the outcome measures, potential confounding variables that may influence the change in the magnitude of the intervention effect were added to the model [54]. Regression coefficients for the group variables (where '0' indicated Control schools, and '1' indicated Intervention schools) reflected average differences in the outcome variables over time adjusted for baseline outcome values, timing of follow-up measures, and *a priori* covariates known to moderate FMS development (gender, age, weight status, CRF, and PA level). To determine the time points at which any intervention effects occurred at (i.e., baseline to post-intervention, or baseline to retention), post-hoc stratified analyses were performed for the Intervention group and the Control group with effect sizes calculated using Cohen's d. Intervention sub-group effect modifier variable interaction terms for gender, weight status, and PA level were subsequently included in separate multilevel analyses [55]. Regression coefficients were assessed for significance using the Wald statistic with statistical significance set at p<0.05. Analyses were performed using MLwiN 2.35 software (Centre for Multilevel Modelling, University of Bristol, UK).

**Results**

In total 22 schools consented to participate in the study (see Figure 1 for response rate, participant breakdown and dropout). Two schools had to withdraw from the study prior to baseline testing (due to a change in PE teacher and principal). A total of 534 participants were recruited for participation in this study. Four hundred and eighty two participants (mean age at baseline=12.78, SD=±0.41) had sufficient data and were included in the analysis. The breakdown of these participants was as follows; male n=246, female n= 236, intervention group n=236, control group n=246. All intervention schools fully engaged in the necessary requirements for inclusion i.e. attending the in-service training, implementing the Y-PATH lessons, facilitating the meeting with parents/guardians and facilitating the meeting with all staff in the school. Preliminary descriptive statistics in Table 1 highlight the descriptive statistics and mean scores of participants at baseline.

**Insert Table 1 here**

*Intervention effects*

Table 2 presents the unadjusted mean skill scores and the results of the adjusted main multilevel analyses. Significant intervention effects across time were observed for Total Object Control (p<.0001) and Total Locomotor (p<.0001), with the greatest improvements evident for Total FMS score (p<.0001). The influence of schools accounted for 11.5% of the variance in adjusted Total Object Control Scores, 4.4% of the variance in Total Locomotor scores, and 9.4% of the variance in Total FMS scores. Post-hoc analyses (Table 3) revealed significant changes for the Intervention group in Total Object Control (p=.002, d=.35) and Total Locomotor scores (p<.0001, d=.17) between baseline and post-intervention, and between baseline and retention (both p<.0001, d=1.31 for Object Control and d=.75 for Locomotor). A significant improvement in Total FMS was observed for the intervention group between baseline and retention (p=.04, d=.45) but not between baseline and post-intervention. For the Control group (Table 4) significant changes were observed for Total Object Control (p=.01, d=.25) and Total FMS (p<.0001, d=.71) between baseline and post-intervention, and between baseline and retention (p=.06, d=.55 and p<.0001, d=.02). A significant improvement in Total Locomotor was observed for the Control group between baseline and post-intervention (p=.004, d=.43) and between baseline and retention (p=.001, d=.4).

**Insert Table 2 here**

**Insert Table 3 here**

**Insert Table 4 here**

*Interaction effects*

Sub-group analyses revealed that the effects of the intervention were significant and positive for all children in the Y-PATH programme regardless of gender, weight status, or physical activity level (p=.03 to <.0001; Table 5). Improvement in Total Locomotor scores was noticeably greater among OWOB children in the intervention group (β=2.25 (95% CI =1.35, 3.15), $p<.0001$) compared to NW peers (β=1.65 (95% CI =0.75, 2.55), $p=.03$).

**Insert Table 5 here**

**Discussion**

This study aimed to evaluate the effectiveness of the Y-PATH intervention in improving adolescent FMS via a RCT. Significant positive intervention effects were observed across time for FMS proficiency regardless of gender, weight status or PA level.

The results indicate in Table 1 that FMS proficiency levels at baseline in this cohort of adolescents were well below the expected levels for their age group. Participants were aged 12-13 years, and therefore according to Gallahue et al. [1] should have achieved mastery across FMS and been at the sport specific skill development stage. The mean age at baseline was 12.8 years (SD=±0.41) which is almost three years after the age children should have mastered all FMS [56]. These results confirm that children are leaving primary school lacking in these basic FMS, which is in agreement with results from O' Brien et al. [16]. This highlights the requirement for a school-based intervention such as Y-PATH to address this lack of proficiency. This is also important when one considers that FMS are the building blocks for sport skill development [56] and also predictors for future participation in PA [14, 30].

The efficacy of the intervention was highlighted by the significant intervention effects which were observed across time. Post hoc results from the multilevel analysis demonstrate that the intervention was effective at improving Total Object Control and Total Locomotor scores between baseline and post-intervention, and baseline and retention (Table 3). The overall efficacy of Y-PATH was highlighted by the significant improvement in overall FMS proficiency between baseline and retention. Zask et al. [57] highlight that there is limited research which report a follow-up or retention assessment of FMS, however in this study the positive results observed were retained three months later at retention. The retention of these results re-enforces the efficacy of the Y-PATH intervention as not only did the intervention group improve locomotor and object control skill proficiency during the eight month intervention but they sustained these results after the intervention had finished. The control group on the other hand only saw significant improvements in locomotor scores between baseline and post-intervention and baseline and retention (Table 4). This improvement is likely due to maturation as children at this age should be developing sport specific skills [1] and therefore it is likely that they may see some improvement in FMS development also. These improvements may also be as a result of having a PE specialist teacher for one year whereas in primary school they had a non-specialist PE teacher.

The results of the exploratory trial for the Y-PATH intervention [35], along with the results of the current study, strongly suggest that school based multi-component interventions can help rectify the lack of FMS proficiency among adolescents; with the Intervention group in the current study improving total FMS score from 95 to almost 100 out of a possible 124. Since adolescence is a period where PA participation decreases [58], it is suggested that an effective intervention such as Y-PATH which targets FMS proficiency while also focusing on improving PA levels may assist in stemming this trend [20].

Sub-group analysis of this study highlight that regardless of gender, weight status and activity level, the Y-PATH intervention was successful at improving FMS proficiency. A previous review highlights a strong positive relationship between FMS and PA in both children and adolescents [14]. As FMS proficiency levels increase among adolescents, it makes them more inclined to participate in PA and sport [59], for this reason it is important that Y-

PATH obtained positive results for both the active and inactive groups. Wrotniak et al. [60] also suggested that targeting FMS proficiency development in children and adolescents may be crucial in counteracting physical inactivity. Hardy et al. [6] state that the low level of FMS proficiency among females may contribute to low levels of PA. This study highlights that Y-PATH is efficient at improving both male and female FMS proficiency and therefore it may be a possible solution for targeting females with low FMS proficiency to prevent them dropping out of PA participation, which is itself correlated with an increase in obesity [17]. Ogden, Carroll, and Curtin [61] highlight that the prevalence of overweight and obesity among children is dramatically increasing worldwide which is having a negative effect on PA levels. Both an increase in weight and a decrease in PA can have a knock on effect on poor FMS levels among children [61]. For this reason, it is important that interventions such as Y-PATH which target FMS proficiency not only see an improvement in the active children's performance, but likewise the inactive and also the overweight/obese cohorts.

The multi-component characteristics of the Y-PATH intervention refers to a holistic approach taken from the onset when the research team designed this intervention [13]. By definition all schools are different, all students are different and the environment surrounding schools and students is also different. The only way to take into account those differences is to offer an intervention that is targeting multiple variables so that the interaction between all elements allows the emergence of a new and unique behaviour. In that instance, we have seen a significant increase of the motor skill proficiency levels over time for the intervention group. This result can only be explained by the multi-component approach of the Y-PATH programme. This intervention has the potential to be replicated in various countries implementing the Y-PATH principles while considering the specificity of each culture. This tailored intervention can specifically target the motor proficiency and physical activity deficiencies for this population (age and gender) while considering the school context (curriculum) and parents/guardians.

As stated by Clark [21] "motor skills do not just come as birthday presents. They must be nurtured, promoted, and practiced" (p.43). Clark [21] argues the importance of teaching FMS right through both primary and secondary school, suggesting that if these skills are not taught then they will not develop to the expected level of proficiency. It is important that children learn these skills when they are young as it may be more challenging to learn them later in life [1]. The findings of this study highlight that with the correct teaching FMS can be improved as suggested by previous research [14, 21]. For future improvements in FMS proficiency, PE teachers and primary non-specialist teachers must receive sufficient training to ensure they are capable and confident at teaching FMS throughout their lessons.

**Conclusions**

This study highlights the lack of FMS proficiency among adolescent youth as they make the transition from primary to post primary education, with participants scoring below the expected proficiency levels for their age group at baseline. Since FMS are seen as a contributor to future participation in PA and sport it is essential that their development becomes a priority in both primary and secondary schools. This study highlights that having an FMS trained PE teacher may assist in achieving improvements in FMS proficiency and should be considered as an option in order to address this problem. This intervention should be considered as an effective method to overturn the lack of FMS proficiency among current adolescents. This study emphasises that multi-component school-based interventions are an effective method of improving FMS proficiency levels among adolescents regardless of gender, weight status and activity levels.

**Strengths, Limitations and Future considerations**

Major strengths of this study were the randomised control trial design used to evaluate an existing intervention programme in the school setting. To ensure the intervention was delivered as intended the teachers in the intervention group received in-service training, resources, a DVD of the proposed lessons and could contact two of the Y-PATH research team at any time they required assistance. The Intervention group teachers also completed lesson evaluations which could be used to track which teachers may require additional encouragement/support. The statistical analysis is also a study strength as it accounted for the fact that students are nested in schools and also takes into account time. Some limitations were that the compliance of participants to wear the activity monitors was not as high as desired despite using various compliance strategies. During FMS data collection, participants get one practice go and two trials which they are assessed on, therefore there is a possibility of a learning effect as this process occurs at three time points over a one year period. Y-PATH was implemented in one first year class in 20 schools in Dublin, Ireland. This implementation was monitored by two full time researchers which were available to answer and deal with any queries teachers may have had as they occurred. For Y-PATH to be implemented on a bigger scale, it would need sufficient man power/financial support to provide this amount of support to ensure that the intervention was implemented as intended. An in-depth analysis should be conducted on the process evaluation of the Y-PATH intervention to highlight any issues which may have arisen during the implementation of a school based intervention such as this. It would also provide the quantitative research in this study with a more in-depth meaning. Finally, to achieve an even greater improvement in FMS proficiency it is recommended to include some extra-curricular activities such as after school or lunch time clubs which could also focus on movement development and physical activity.

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**Table 1. Descriptive statistics overview and mean scores at baseline**

| | Intervention | Control |
|---|---|---|
| Males n= | 116 | 130 |
| Females n= | 120 | 116 |
| Age | 12.77SD=±0.41 | 12.78 SD=±0.42 |
| BMI | 20.43 SD=±3.30 | 19.79 SD=±3.02 |
| Locomotor (max possible score=66) | 51.75 SD=±5.91 | 51.40 SD=±5.72 |
| Object Control (max possible score=48) | 36.60 SD=±4.42 | 37.29 SD=±4.12 |
| Total FMS (max possible score=124) | 94.83 SD=±8.39 | 94.55 SD=±8.50 |
| MVPA min/day | 52.56 SD=±19.22 | 53.61 SD=±23.79 |

MVPA=moderate-vigorous Physical Activity, BMI=Body Mass Index, FMS=Fundamental Movement Skills

**Table 2. Unadjusted mean Total Object Control, Total Locomotor, and Total FMS scores with adjusted average intervention effects over time**

| | Intervention | | | Control | | | Adjusted model[a] | |
|---|---|---|---|---|---|---|---|---|
| Outcome | Baseline | Post-intervention | Retention | Baseline | Post-intervention | Retention | β (95% CI) | p |
| Total Object Control | 36.65 SD=±4.42 | 38.66 SD=±7.01 | 42.52 SD=±4.52 | 37.44 SD=±4.12 | 36.13 SD=±6.35 | 40.06 SD=±5.44 | 2.04 (1.16, 2.92) | <.0001 |
| Total Locomotor | 52.05 SD=±5.91 | 50.31 SD=±14.81 | 57.06 SD=±7.40 | 51.49 SD=±5.72 | 48.65 SD=±12.89 | 54.49 SD=±7.60 | 2.13 (1.44, 2.82) | <.0001 |
| Total FMS | 95.12 SD=±8.39 | 86.78 SD=±25.95 | 99.61 SD=±11.70 | 94.71 SD=±8.51 | 83.85 SD=±22.05 | 94.50 SD=±11.99 | 4.04 (2.39, 5.69) | .0001 |

Notes. CI =confidence interval. β values represent the average intervention effects (i.e., between-group differences) over time.

[a] Adjusted for baseline values of the outcome variables, timing of follow-up measures, gender, age, weight status, CRF, and physical activity level.

**Table 3. Post-hoc analysis of adjusted change in Intervention group scores between baseline and post-intervention, and baseline and retention.**

| Outcome | Adjusted[a] change from baseline to post-intervention β (95% CI) | p | d | Adjusted[a] change from baseline to retention β (95% CI) | p | d |
|---|---|---|---|---|---|---|
| Total Object Control | 2.13 (0.78, 3.48) | .002 | 0.35 | 5.79 (4.32, 7.26) | <.0001 | 1.31 |
| Total Locomotor | 2.04 (0.81, 3.27) | <.0001 | 0.17 | 4.39 (2.82, 5.96) | <.0001 | 0.75 |
| Total FMS | -2.29 (-4.70, 0.12) | .06 | 0.49 | 3.26 (0.16, 6.36) | .04 | 0.45 |

Notes. CI =confidence interval. β values represent the Intervention group adjusted change from baseline.
[a] Adjusted for baseline values of the outcome variables, gender, age, weight status, CRF, and physical activity level.

**Table 4. Post-hoc analysis of adjusted change in Control group scores between baseline and post-intervention, and baseline and retention.**

| Outcome | Adjusted[a] change from baseline to post-intervention β (95% CI) | p | d | Adjusted[a] change from baseline to retention β (95% CI) | p | d |
|---|---|---|---|---|---|---|
| Total Object Control | -1.14 (-2.04, -0.24) | .01 | 0.25 | 1.62 (-0.05, 3.29) | 0.06 | 0.55 |
| Total Locomotor | -1.92 (-3.23, -0.61) | .004 | 0.43 | 2.85 (1.16, 4.54 ) | .001 | 0.40 |
| Total FMS | -9.21 (-11.27, -7.15) | <.0001 | 0.71 | -1.38 1.59 (-4.49, 1.74) | .39 | 0.02 |

Notes. CI =confidence interval. β values represent the Intervention group adjusted change from baseline.
[a] Adjusted for baseline values of the outcome variables, gender, age, weight status, CRF, and physical activity level.

**Table 5. Intervention sub-group interactions average change over time**

| Interactions | Total Locomotor β (95% CI) | p | Total Object Control β (95% CI) | p | Total FMS β (95% CI) | p |
|---|---|---|---|---|---|---|
| **Intervention x gender** | | | | | | |
| Boys | 2.32 (1.26, 3.38) | <.0001 | 2.16 (1.16, 3.16) | <.0001 | 4.26 (2.33, 6.18) | <.0001 |
| Girls | 2.22 (1.32, 3.12) | <.0001 | 1.91 (1.0, 2.81) | <.0001 | 3.94 (2.23, 5.65) | <.0001 |
| **Intervention x weight status** | | | | | | |
| Normal weight | 1.65 (0.20, 3.10) | .03 | 2.41 (1.16, 3.66) | <.0001 | 4.07 (1.62, 6.52) | .001 |
| Overweight/obese | 2.25 (1.35, 3.15) | <.0001 | 1.95 (1.04, 2.85) | <.0001 | 4.04 (2.33, 5.75) | <.0001 |
| **Intervention x physical activity level** | | | | | | |
| Active | 2.18 (1.12, 3.24) | .0001 | 1.95 (0.95, 2.95) | <.0001 | 4.03 (2.09, 5.97) | <.0001 |
| Inactive | 2.07 (1.03, 3.11) | <.0001 | 2.13 (1.07, 3.19) | <.0001 | 4.06 (2.14, 5.98) | <.0001 |

Notes. CI =confidence interval. β values represent the Intervention group adjusted[a] change over time from baseline for each sub-group effect modifier (e.g., for gender, boys' and girls' results are reported).

[a] Adjusted for baseline values of the outcome variables, timing of follow-up measurements, interaction term, gender, age, weight status, CRF, and physical activity level.

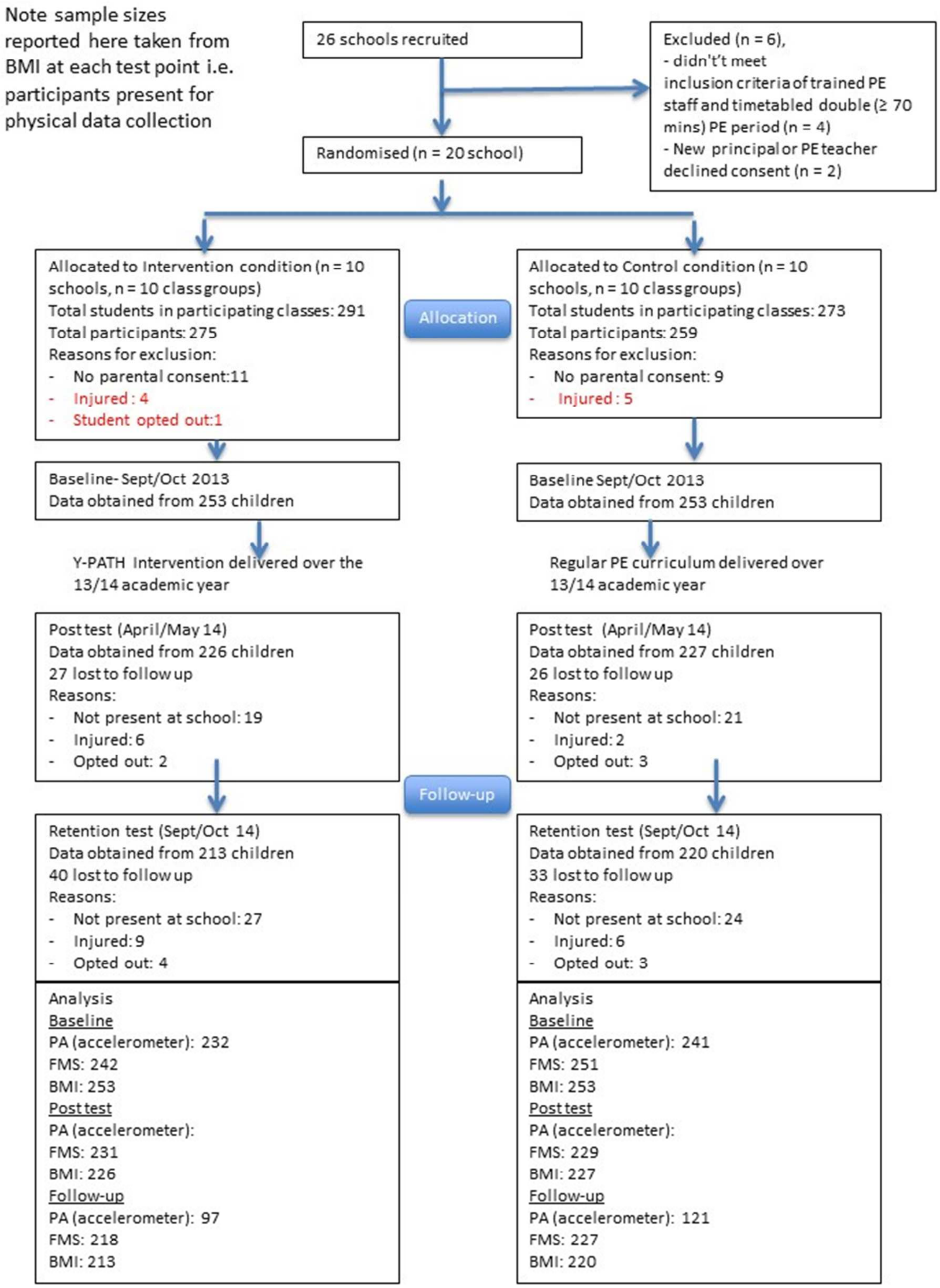


**Figure 1. Description of participants included in the study**

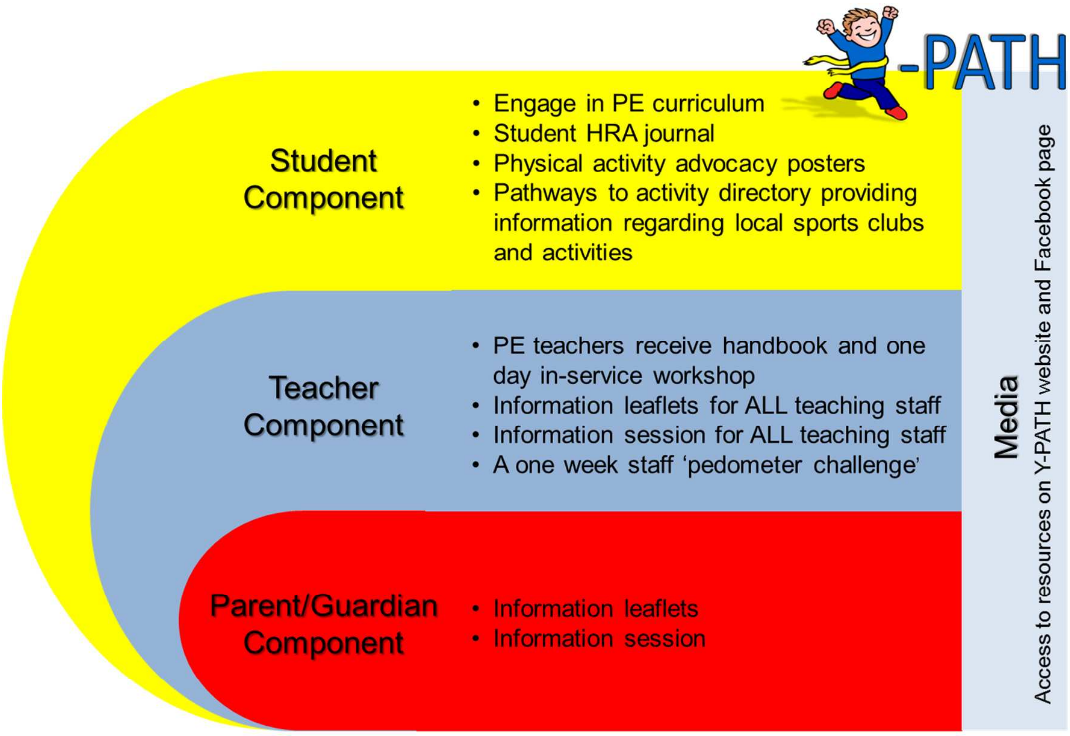


**Figure 2. Overview of the Y-PATH structure**

| Section/Topic | Item Number | Checklist Item |
|---|---|---|
| **Title and abstract** | 1a | Identification as a randomized trial in the title |
| | 1b | Structured summary of trial design, methods, results, and conclusions (for specific guidance, see CONSORT for abstracts [21, 31]) |
| **Introduction** | | |
| Background and objectives | 2a | Scientific background and explanation of rationale |
| | 2b | Specific objectives or hypotheses |
| **Methods** | | |
| Trial design | 3a | Description of trial design (such as parallel, factorial), including allocation ratio |
| | 3b | Important changes to methods after trial commencement (such as eligibility criteria), with reasons |
| Participants | 4a | Eligibility criteria for participants |
| | 4b | Settings and locations where the data were collected |
| Interventions | 5 | The interventions for each group with sufficient details to allow replication, including how and when they were actually administered |
| Outcomes | 6a | Completely defined prespecified primary and secondary outcome measures, including how and when they were assessed |
| | 6b | Any changes to trial outcomes after the trial commenced, with reasons |
| Sample size | 7a | How sample size was determined |
| | 7b | When applicable, explanation of any interim analyses and stopping guidelines |
| Randomization | | |
| Sequence generation | 8a | Method used to generate the random allocation sequence |
| | 8b | Type of randomization; details of any restriction (such as blocking and block size) |
| Allocation concealment mechanism | 9 | Mechanism used to implement the random allocation sequence (such as sequentially numbered containers), describing any steps taken to conceal the sequence until interventions were assigned |
| Implementation | 10 | Who generated the random allocation sequence, who enrolled participants, and who assigned participants to interventions |
| Blinding | 11a | If done, who was blinded after assignment to interventions (for example, participants, care providers, those assessing outcomes) and how |
| | 11b | If relevant, description of the similarity of interventions |
| Statistical methods | 12a | Statistical methods used to compare groups for primary and secondary outcomes |
| | 12b | Methods for additional analyses, such as subgroup analyses and adjusted analyses |
| **Results** | | |
| Participant flow (a diagram is strongly recommended) | 13a | For each group, the numbers of participants who were randomly assigned, received intended treatment, and were analyzed for the primary outcome |
| | 13b | For each group, losses and exclusions after randomization, together with reasons |
| Recruitment | 14a | Dates defining the periods of recruitment and follow-up |
| | 14b | Why the trial ended or was stopped |
| Baseline data | 15 | A table showing baseline demographic and clinical characteristics for each group |
| Numbers analyzed | 16 | For each group, number of participants (denominator) included in each analysis and whether the analysis was by original assigned groups |
| Outcomes and estimation | 17a | For each primary and secondary outcome, results for each group, and the estimated effect size and its precision (such as 95% confidence interval) |
| | 17b | For binary outcomes, presentation of both absolute and relative effect sizes is recommended |
| Ancillary analyses | 18 | Results of any other analyses performed, including subgroup analyses and adjusted analyses, distinguishing prespecified from exploratory |
| Harms | 19 | All important harms or unintended effects in each group (for specific guidance, see CONSORT for harms [28]) |
| **Discussion** | | |
| Limitations | 20 | Trial limitations; addressing sources of potential bias; imprecision; and, if relevant, multiplicity of analyses |
| Generalizability | 21 | Generalizability (external validity, applicability) of the trial findings |
| Interpretation | 22 | Interpretation consistent with results, balancing benefits and harms, and considering other relevant evidence |
| **Other information** | | |
| Registration | 23 | Registration number and name of trial registry |
| Protocol | 24 | Where the full trial protocol can be accessed, if available |
| Funding | 25 | Sources of funding and other support (such as supply of drugs), role of funders |

CONSORT = Consolidated Standards of Reporting Trials.
* We strongly recommend reading this statement in conjunction with the CONSORT 2010 Explanation and Elaboration (13) for important clarificatior If relevant, we also recommend reading CONSORT extensions for cluster randomized trials (11), noninferiority and equivalence trials (12), nonpharma (32), herbal interventions (33), and pragmatic trials (34). Additional extensions are forthcoming: For those and for up-to-date references relevant to www.consort-statement.org.

**Figure 3. Overview of CONSORT Guidelines**[44]