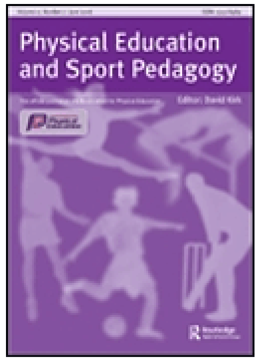

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Effects of an 8-week school-based intervention programme on Irish school children's fundamental movement skills.

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Abstract

Background: Irish school children have demonstrated poor proficiency in fundamental movement skills (FMS) and consistent with international literature, females and overweight children tend to be less skilled than males and non-overweight children. Interventions that are suitable for children of all abilities and which provide long-term improvements in FMS proficiency are warranted.

Purpose: This study examined the immediate and long-term effects of an 8-week FMS intervention programme on 255 Year 3 and 4 Irish school children's (50% male, 7.4±0.6yr) FMS proficiency levels. It was hypothesised that using a mastery motivational climate to deliver the intervention sessions would provide immediate and long-term improvements for all children, including females and overweight children.

Methods: Participants were conveniently recruited from 4 schools and randomly assigned to the intervention-control (Group I-C: 2 schools, n=134, 48% male) or control-intervention (Group C-I: 2 schools, n=121, 52% male) sequence. Group I-C completed the intervention (i.e. two 45-minute FMS classes per week in place of usual PE for 8 weeks) in phase 1, and after a 4-week washout, completed the control condition (i.e. routine PE lessons for 8 weeks) in phase 2, and vice-versa for Group C-I. FMS proficiency, assessed using the Test of Gross Motor Development-Third edition, and weight status based on body mass index (BMI) were recorded at 5 time points: pre and post phase 1, pre and post phase 2 and at 13-months post-intervention (i.e. follow-up).

Results: Linear mixed models revealed significant group × time interaction effects for locomotor, ball skills and total FMS scores (all $p<0.001$) following engagement in the FMS intervention. No significant changes were observed following engagement in the control condition (i.e. Group C-I: pre to post phase 1 and Group I-C: pre to post phase 2; all $p>0.05$). Significant improvements for locomotor, ball skills and total FMS scores were reported for both groups at follow-up compared to baseline (all $p<0.001$). No significant group × time × gender or group × time × weight status interaction effects were reported (all $p>0.05$). The proportion of participants who improved from poor-mastery to mastery/near-mastery was significant for 8 skills, immediately following the intervention and from baseline to follow-up.

Conclusion: Significant improvements in FMS proficiency were observed following a short-duration intervention that was delivered by an instructor with specialist FMS knowledge and an ability to create a mastery-oriented climate during lessons. Although the long-term effectiveness remains unclear, it is likely that mastery-oriented PE lessons could facilitate greater improvements in FMS development for children of all abilities compared to traditional PE lessons. Future studies should explore if primary teachers feel they have sufficient confidence and pedagogical skills to support children's FMS development during PE.

Keywords: motor competence, physical activity, physical education, weight status, health

Introduction

Fundamental movement skills (FMS) are described as the building blocks of physical activity, and include locomotor (e.g., run, gallop, skip), object-control (e.g., throw, catch, kick) and stability skills (e.g., single leg stance) (Gallahue, Ozmun and Goodway 2012). Achieving proficient levels of FMS is associated with physical and mental health-related benefits including higher levels of physical activity (Holfelder and Schott 2014; Barnett et al., 2011; Laukkanen et al., 2014), maintenance of a healthy weight status (Slotte et al., 2017; Bryant et al., 2014; Southall et al., 2004; O'Brien et al., 2016; Okely et al., 2004; Catuzzo et al. 2016), enhanced physical self-perceptions (Babic et al., 2014), better cognitive function (Draper et al. 2012; van der Fels, et al. 2015) and improved cardiorespiratory fitness (Hardy et al., 2012; Catuzzo et al., 2016).

During early childhood, children need to engage in regular physical activity in order to develop their FMS (Stodden et al. 2008; Robinson et al. 2016). However, only 17% of Irish primary school children are meeting the daily physical activity guidelines (Woods et al. 2018), which indicates that the majority of these children have limited opportunities to develop their skills. Engagement in physical activity and sport declines as children get older, with only 10% of Irish secondary school students meeting the daily physical activity guidelines (Woods et al. 2018). Some of this drop-off could be attributed to inadequate FMS development during the early years (Robinson et al. 2015; Stodden et al. 2008). As children get older and their cognitive awareness improves, they can more accurately perceive their ability to perform skills (Robinson et al. 2015; Babic et al. 2014). Consequently, children with poorer FMS may lose confidence and motivation to continue participating in regular physical activity and sport (Loprinzi, Davis and Fu 2015), which increases their risk of becoming overweight or obese and subsequently developing obesity-related diseases as they get older (Craig et al. 2008; Freedman et al. 2001).

Despite having the potential to master most FMS by the age of 6 years (Gallahue, Ozmun and Goodway 2012), over 50% of Irish primary school children (Bolger et al. 2018; Kelly et al. 2019; Behan et al. 2019) and secondary school adolescents (O'Brien, Belton and Issartel 2016; Lester et al. 2017) are not mastering many FMS. Furthermore, females generally display poorer object-control skill proficiency than males (Behan et al. 2019; O'Brien et al. 2016, Bolger et al. 2018; Hardy et al. 2010; van Beurden et al. 2003) and overweight children demonstrate inferior locomotor and object-control skill proficiency than their non-overweight peers (Hume et al., 2008; Bryant et al., 2014; Morano et al., 2011; Slotte et al., 2015; Catuzzo et al., 2016). Given that the ideal window of opportunity for developing FMS is proposed to be between 3- and 8-years old (Gallahue, Ozmun and Goodway 2012; Clark 2005), FMS interventions should be implemented during early primary school years.

The Test of Gross Motor Development (TGMD) editions 1, 2 and 3 are commonly used process-oriented assessment tools to measure children's FMS proficiency and development (Hulteen et al. 2020; Logan et al. 2018). Skill performances are observed and scored based on the presence or absence of pre-determined criteria to assess movement quality (i.e. the throwing technique) rather than movement outcome (i.e. how far one can throw) (Ulrich 2000; Bardid et al. 2019). In addition to raw scores, categorical variables can be created to classify skill performances by mastery level (i.e. mastery/near mastery or poor mastery) (Hands 2002). Both methods are commonly used to evaluate the effectiveness of school-based FMS interventions, where the mean raw values track changes in subtest scores and mastery categories monitor changes across individual skills (O'Brien et al. 2016; Bolger et al., 2018). As opposed to product-oriented assessments, process-oriented assessments are less influenced by biological factors like strength and size and are thus useful to compare FMS performances by sex and weight status (Haywood, Roberton and Getchell 2012).

Quality instruction and feedback opportunities are essential for FMS development (Gallahue, Ozmun and Goodway 2012; Morgan et al. 2013; Chan et al. 2016; Robinson et al. 2012) with much evidence highlighting the benefits of pedagogical practices that emphasise a mastery-oriented climate to enhance intrinsic motivation (Standage, Duda and Ntoumanis, 2003) and maximise students' engagement in (Solmon 1996) and enjoyment of PE lessons (Vasconcellos et al. 2019; Ntoumanis and Biddle 1999). A mastery-motivational climate can be achieved by ensuring the learner's basic needs of competence, autonomy and relatedness are met during lessons. Short-duration interventions emphasising a mastery-motivational climate have led to significant improvements in FMS proficiency among pre-school aged children, compared to non-mastery climates (Wick et al., 2017; Robinson and Goodway 2009; Valentini and Rudisill, 2004). In the study by Valentini and Rudisill (2004), improvements in FMS were maintained at 6-month follow-up compared to post-intervention scores; however, Robinson and Goodway (2009) reported a significant decline in FMS at 9-week follow-up compared to post-intervention, but scores remained significantly higher than baseline. In the same study, FMS scores did not significantly change at post-intervention or at 9-week follow-up for the control group. These studies suggest that an instructional climate that fosters students' autonomy and emphasises self-improvement rather than competition and winning can promote lasting FMS improvements.

Previous investigations suggest that multi-component school-based interventions, which are delivered over a full academic year and underpinned by a theoretical framework, can support FMS improvements immediately following the intervention (Van Beurden et al. 2003; Lai et al. 2014; Tompsett et al. 2017; Bolger et al. 2019). However, it is difficult to decipher the most influential elements of such programmes and a lack of follow-up studies means their long-term effectiveness remains unclear (Lai et al. 2014). Due to time constraints and large curriculum demands, school-based interventions may benefit from taking a more streamlined approach. Thus, the specific elements of what makes an intervention programme effective must be identified. There is evidence to suggest that mastery-based interventions can enhance enjoyment of PE (Navarro-Patón et al. 2019) and increase primary school children's motivation to be physically active (Sproule et al. 2007). However, the effectiveness of short-duration programmes to enhance FMS proficiency levels within a typical primary school PE class is yet to be determined (Bandeira et al. 2017).

Therefore, the aim of this study was to investigate if an 8-week FMS intervention programme, delivered using a mastery-motivational climate, can significantly improve FMS proficiency levels among primary school children. A secondary aim was to examine potentially differential intervention effects according to children's sex and weight status. It was hypothesised that engaging in the intervention programme would significantly improve FMS proficiency levels for all children regardless of sex or weight status, and that these improvements would be maintained 13-months post-intervention.

Methods

A longitudinal cluster crossover design was employed to investigate the effects of an 8-week FMS intervention programme on FMS proficiency levels immediately post-intervention and at 13-months post-intervention (i.e. follow-up). The crossover design ensured that all participants in each school were provided with the opportunity to participate in the FMS programme which was critical for the recruitment process. Ethical approval was granted by the Institute's research ethics board.

Participants and setting

An a priori sample size calculation was used to determine the study size using the standard deviation of a previously conducted study with a similar study design (Draper et al. 2012). With $\alpha=0.05$, power=0.8, detectable difference=1 and standard deviation=2.4, the projected sample size required minimally 186 participants in total. To account for a drop-out rate of 15%, a minimum of 214 participants had to be recruited for this study.

Participants (N=255) were conveniently recruited from Year 3 (Age: 6.9±0.4 yrs.) and Year 4 (Age: 7.9±0.4 yrs.) mainstream classes, from 4 schools in the midlands of Ireland. As the principal investigator was delivering all lessons, only four schools could be accepted into the study. Schools were informed that acceptance to the study would be granted on a first come basis, whilst others would be held as reserves should any issues arise prior to the study commencing. Preceding baseline data collection, informed consent by legal guardians and assent by eligible participants were provided. Children who failed to return signed consent forms or those with a musculoskeletal injury, disability or medical condition that limited their ability to participate in physical activity were excluded. Children with mild learning disabilities who had no difficulty following instructions were included in the study. The class teacher planned and supervised alternative activities for children who did not participate in the testing.

Procedures

At baseline, all participants in two schools were randomly assigned to the intervention-control (I-C) sequence and all participants in the remaining 2 schools to the control-intervention (C-I) sequence. Group I-C completed the intervention in phase 1 (P1) and the control condition (i.e. normal PE) in phase 2 (P2), whereas group C-I followed the reverse sequence. The intervention was implemented in place of usual PE lessons. P1 and P2 were separated by a 4-week washout (i.e. point of crossover), during which both groups were on school holidays and, therefore, not engaging in physical education or the intervention.

Figure 1 outlines the study process and the number of participants with complete TGMD-3 data at each time point. Reasons for missing data included illness, injury and family holidays. Outcome measures were assessed for all participants at five time points where time 1 (T1) was baseline/phase 1 pre-test, time 2 (T2) phase 1 post-test, time 3 (T3) post 4-week washout/phase 2 pre-test, time 4 (T4) phase 2 post-test and time 5 (T5) was at 13-months post-intervention.

****Insert Figure 1 near here****

Instruments

FMS were assessed using the valid (Temple and Foley 2017; Valentini, Zanell and Webster 2016) and reliable (Rintala, Sääkslahti and Iivonen 2017; Hulteen et al. 2020) Test of Gross Motor Development-Third Edition (TGMD-3) which includes 13 skills, namely the run, gallop, hop, skip, slide and horizontal jump in the locomotor skills category and the two-hand strike, forehand strike, kick, catch, dribble, overhand throw and underhand throw in the ball skills category (formerly object-control skills) (Ulrich 2019).

Anthropometric measurements were also recorded at each time point. Height was measured to the nearest 0.1 cm, using a portable height stadiometer (SECA 217, SECA ltd., Leicester, UK) and body mass to the nearest 0.1 kg, using a portable SECA heavy-duty scale (SECA colorata 760, SECA ltd., Leicester, UK). Body Mass Index (BMI) was derived using the equation: body mass (kg)/height (m^2). Participants were categorised as either overweight/obese or non-overweight according to the age- and gender-specific International Obesity Task Force cut-off points (Cole et al. 2000).

Intervention details

The principal investigator with over eight years' experience coaching children (mainly in athletics) and a certificate in Coaching Children from Coaching Ireland (focusing on physical literacy), delivered all intervention sessions in each school's indoor sports hall. The intervention replaced PE lessons and consisted of two 45-minute sessions per week over 8 weeks (i.e. a total of 16 sessions, 720 minutes). The class teacher arranged and supervised alternative activities for non-participating children and did not assist with the intervention in any way. Similar to the structure of a previous community-based intervention, three skills were targeted during each lesson (Bardid et al. 2017).

Although the TGMD-3 includes 13 skills, overhand and underhand throwing were grouped together, allowing for each skill to be included four times throughout the 8-week intervention. Each lesson started with a warm-up, which also included a quick discussion on the skills being targeted in the session (10 minutes), two or three separate games/activities (30 minutes) and a cool-down which also incorporated some questioning and discussion on the skills just practiced (5 minutes). Intervention sessions were delivered using the principles of the TARGET acronym (i.e. task, authority, recognition, grouping, evaluation and time) to facilitate a mastery-motivational climate (Ames 1992). An overview of the theoretical underpinning of the lesson structure which was informed by Achievement Goal Theory (Nicholls, 1984) and Self-Determination Theory (Deci and Ryan 2008) is included in the supplementary material.

During the control condition, teachers were asked to continue with their usual PE routine. Teachers typically taught one 60-minute class per week focusing on one of the six strands in the Irish PE curriculum (i.e. athletics, dance, gymnastics, aquatics, outdoor and adventure, and games). The exact content, duration or frequency of the control condition for each school was not monitored.

FMS assessment

Participants were video recorded performing two trials of each skill which were retrospectively scored by the principal investigator, who was not blinded to the cluster randomisation. Scores for the six locomotor skills and seven ball skills were summed to determine the locomotor subtest (max possible score=46) and ball skill subtest (max possible score=54) scores, respectively. Both subtest scores were added to give the total FMS score (max possible score=100). Two weeks before baseline data collection, the principal investigator completed inter-rater reliability scoring of the TGMD-3 using the online resource on the TGMD-3 website (Reliability Videos - TGMD-3, 2016). The principal investigator submitted scores for four participants performing the 13 skills. The scoring was analysed by an expert who returned a reliability agreement score of 99%. The principal investigator then completed intra-rater reliability by assigning scores to a randomly selected subset of videos from 32 participants (i.e. 16 from Group I-C and 16 from Group C-I) performing each of the 13 skills two weeks after baseline data collection. These videos were rescored two-weeks later. ICC values ranged from good ICC=0.79 (run) to excellent ICC=0.98 (kick) (Koo and Li 2016). The detailed testing and scoring procedures are described in a previous study (Kelly et al. 2019).

Data analysis

All data were analysed using IBM SPSS software version 25 (SPSS Inc. Chicago, IL). Significance was set at $p<0.05$. All data were determined to be normally distributed. Independent T-tests were used to assess the differences in age, locomotor subtest, ball skills subtest and total FMS mean scores between Groups I-C and C-I at baseline. Additionally, Chi-square analysis were run to compare the distribution of participants according to sex and weight status in each group at baseline.

The intention-to-treat principle was applied as it limits the risk of bias and provides a more accurate estimate of the effects of the intervention compared to a per protocol analysis (McCoy 2017). Linear mixed models were conducted to assess the effects of the intervention programme on FMS outcome measures (locomotor subtest score, ball skills subtest score and total FMS score) over time. Group (I-C, C-I), time (pre-phase 1[T1], post-phase 1[T2], pre-phase 2 [T3], post-phase 2 [T4], 13-months post-intervention [T5]) and group-time interaction formed the base of the model as fixed effects. Class group (Year 3/Year 4) was included as a random effect using the variance components covariance matrix. The individual participants as part of each school cluster were assessed as a repeated effect using the unstructured covariance matrix. Additionally, a group-time-sex interaction was included to investigate potential sex effects (i.e. males versus females) and a group-time-weight status interaction was included to investigate any weight status effect (i.e. non-overweight versus overweight-obese). Bonferroni adjustments for multiple comparisons were applied to limit the risk of type-1 error. Effect sizes were calculated using Cohen's d where d = 0.2, 0.5 and 0.8 represented small, medium and large effect sizes, respectively (Cohen 1988).

Finally, a binary variable was computed to define mastery/near-mastery (MNM) or poor mastery (PM) for each skill (Kelly et al. 2019; O'Brien et al. 2016; O'Brien, Belton and Issartel 2016). Mastery was assigned when a maximum score was achieved for a skill, and near mastery assigned when all but one skill criteria was correctly performed over two trials. Poor mastery was assigned when more than one skill criteria was incorrect/absent over the two trials (O'Brien et al. 2016; van Beurden et al. 2002). McNemar tests were run to identify if the proportion of participants achieving MNM for each skill significantly improved from pre to post phase 1, from pre to post phase 2 and from baseline to follow-up. Effect sizes were determined by calculating the Odds Ratio and classified as small (1.5), medium (3.5) and large (9.0) (Cohen 1988).

Results

Baseline characteristics are outlined in Table 1. Participants in Group I-C and C-I were similar at baseline for age, locomotor subtest, ball skills subtest and total FMS scores ($p>0.05$). Additionally, the distribution of participants by sex and weight status were similar across both groups ($p>0.05$).

Phase 1 (T1 to T2)

Linear mixed models revealed significant group by time interaction effects for the locomotor subtest (Figure 2), ball skills subtest (Figure 3) and total FMS scores (Figure 4). Group I-C showed a medium significant improvement from T1 to T2 for the locomotor subtest ($p<0.001$, $d=0.6$), and a large significant improvement for the ball skills and total FMS scores (both $p<0.001$, $d=1.0$). FMS scores did not change significantly for Group C-I during phase 1.

Washout (T2 to T3)

Locomotor subtest [mean difference: 1.2 (95% CI: 0.2, 2.1), $p=0.02$], ball skills subtest [mean difference: 3.8 (95% CI: 2.8, 4.8), $p<0.001$] and total FMS [mean difference: 5.0 (95% CI: 3.5, 6.5), $p<0.001$] scores significantly decreased for Group I-C during the washout phase (i.e. T2 to T3). There was no significant change in the locomotor subtest score for Group C-I during the washout phase ($p>0.05$), but their ball skills subtest [mean difference: -2.9 (95% CI: -4.0, -1.9), $p<0.001$] and total FMS scores [mean difference: -4.0 (95% CI: -5.5, -2.5), $p<0.001$] significantly increased. Locomotor subtest [**Group I-C**: mean difference: -2.2 (95% CI: -3.6, -0.7), $p<0.001$; **Group C-I**: mean difference: -1.3 (95% CI: -2.7, 0.6), $p=0.07$], ball skills subtest [**Group I-C**: mean difference: -2.6 (95% CI: -4.1, -1.1), $p<0.001$; **Group C-I**: mean difference: -2.9 (95% CI: -4.5, -1.4), $p<0.001$] and total FMS scores [**Group I-C**: mean difference: -6.7 (95% CI: -6.7, -2.2), p<0.001; **Group C-I**: mean difference: -4.3 (95% CI: -6.5, -2.2), p<0.001] were significantly higher than baseline values after the washout phase (i.e. T1 versus T3) for both groups, apart from Group C-I's locomotor subtest scores. Groups I-C and C-I had similar locomotor subtest [mean difference: 1.2 (95% CI: -0.1, 2.5), p=0.08], ball skills subtest [mean difference: 0.7 (95% CI: -1.0, 2.4), p=0.4] and total FMS scores [mean difference: 1.7 (95% CI: -0.8, 4.3), p=0.2] after the washout phase (i.e. at T3).

Phase 2 (T3 to T4)

A medium significant improvement for the locomotor subtest and total FMS (both p<0.001, d=0.6) scores, in addition to a small significant improvement in the ball skills subtest scores (p<0.001, d=0.4), was observed for Group C-I after the intervention (i.e. T4 versus T3). FMS scores for Group I-C did not change significantly from T3 to T4.

Follow-up

Compared to baseline scores, both groups maintained a significant improvement in their locomotor subtest, ball skills subtest and total FMS scores at follow-up. The effect size was small for both groups in the locomotor subtest scores (I-C: p=0.02, C-I: p<0.001, both d=0.4), whilst for the ball skills subtest and total FMS scores, Group I-C revealed medium effect sizes (both p<0.001, both d=0.7) and Group C-I large effect sizes (both p<0.001, d=1.0 and 0.9, respectively).

Sex and weight status effects

Linear mixed models revealed no significant sex-group-time interaction effects or sex-time interaction effects for the locomotor subtest, ball skills subtest or total FMS scores (all p>0.05). There was, however, a significant main effect for sex, for the ball skills subtest [mean difference: 4.6 (95% CI: 3.4, 5.8), p<0.001] and total FMS scores [mean difference: 3.8 (95%

CI: 1.8, 5.9), $p<0.001$] with males outperforming females on both aspects. There was no significant difference between males and females for the locomotor subtest scores ($p>0.05$).

There were no significant weight status-group-time interaction effects for either subtest or total FMS scores ($p>0.05$). However, overweight/obese participants had significantly lower total FMS scores than non-overweight participants, which was consistent over time [mean difference: 2.6 (95% CI: 0.8, 4.4), $p=0.005$]. Non-overweight participants had significantly higher locomotor subtest scores ($p<0.001$); however, there was also a significant time-weight status interaction effect ($p=0.04$). Pairwise comparison revealed that non-overweight participants had significantly higher locomotor subtest scores than overweight/obese participants at each time point apart from T2. Overweight and non-overweight participants did not differ significantly at any time point for the ball skills subtest scores ($p>0.05$).

****Insert Table 1 near here****

****Insert Figure 2, 3 & 4 near here****

Individual skill changes

McNemars test indicated that mastery levels changed in the direction of poor mastery (PM) to mastery/near mastery (MNM) for eight skills from pre to post-intervention (Table 2) and from baseline to follow-up (Table 3). Significant improvements were reported for the gallop, horizontal jump, forehand strike, overhand throw, dribble, kick, underhand throw and run for Group I-C in phase 1 and for the gallop, horizontal jump, forehand strike, overhand throw, dribble, hop, skip and slide for Group C-I in phase 2 (Table 2). A decrease in the proportion of participants achieving MNM was observed for the horizontal jump for Group C-I in phase 1, and for the overhand throw for Group I-C in phase 2 (Table 2). From baseline to follow-up, mastery levels significantly changed in the direction of PM to MNM for the gallop, skip, two-hand strike, forehand strike, kick, underhand throw, catch and dribble (Table 3). Table 2 and 3 also summarise the proportion of participants achieving MNM at each time point.

****Insert Tables 2 and 3 near here****

Discussion

This is the first study to examine if a short-duration FMS intervention programme can provide immediate and long-term improvements in Irish primary school children's FMS proficiency levels, and internationally is among the first of its kind to include older children who are attending primary school rather than pre-school. The findings support the hypothesis that an FMS intervention programme, delivered by a specialist coach over 8 weeks, can improve FMS proficiency immediately post-intervention for children with varying levels of ability. However, further studies are needed to clarify if improvements can be maintained over time.

Similar to previous research (Gallahue, Ozmun and Goodway 2012; Palmer et al. 2017; Logan et al. 2012; Morgan et al. 2013; Chan et al. 2016; Robinson and Goodway, 2009; Robinson et al. 2012), the current study results suggests that children may be more likely to master FMS if they receive developmentally appropriate specialist instruction and practice opportunities. Large and medium effect sizes were reported for the within group change in total FMS scores following engagement in the intervention in phase 1 and 2, respectively. Despite the difference in the magnitude of improvement, both groups had similar mean FMS scores after their respective intervention phases (Group I-C at T2: 64.1 versus Group C-I at T4: 63.4). The difference in effect sizes were likely due to Group C-I having a higher FMS score before starting their intervention (57.4 at T3) compared to that of Group I-C prior to their intervention (54.5 at T1). Logan et al. (2013) similarly found that lower skilled children improved more than higher skilled children following a 9-week object-control skill intervention, indicating that improvements are more difficult to obtain as skill levels improve. Although a ceiling effect is possible when assessing FMS using the TGMD (Logan et al. 2018), this was unlikely in the current study as no child achieved a maximum FMS score at any time point.

In contrast, 8 weeks of routine PE lessons did not lead to any significant change in FMS scores in either phase 1 or 2 in the current study. Although the content of the PE lessons is unknown, previous research in both Ireland (Bolger et al. 2019) and Australia (Cohen et al. 2015) similarly found no improvements in FMS proficiency levels following 8 months of usual PE. In many countries, PE is delivered by generalist teachers, most of whom have limited PE specific training (Hardman 2007). Consequently, generalist teachers tend to revert to their own experiences of PE as a child to guide their teaching (Morgan and Hansen 2008) with many of them overemphasising the games strand of the PE curriculum (Woods et al. 2018; Hardman 2007). Games based PE lessons can be beneficial if delivered in a non-competitive setting (Smith 2016); however, they are traditionally associated with competition and winning. Overemphasis on competition and winning facilitates an ego-based motivational climate (Ames 1992), which can lead to disengagement, amotivation and negative emotional experiences among lower skilled children (Garcia-Gonzales et al. 2019; Braithwaite, Spray, and Warburton 2011). Although speculative, this may be a reason why Irish primary school children struggle to develop their FMS proficiency during typical PE lessons. Further research is needed to clarify what is taught in PE and how it is taught, but perhaps teachers require upskilling on how to deliver lessons through a mastery-oriented climate (i.e. encouraging children to focus on self-improvement, rewarding individual effort and progress and avoiding social comparison and overly competitive environments) in order to facilitate FMS improvements.

Following the 4-week washout phase (at T3), FMS scores were not significantly different between both groups. Compared to T2, FMS scores at T3 significantly decreased for Group I-C. Since regular practice is essential to learning (Wulf, Shea and Lewthwaite 2010; Wulf 1991), this decrease may be due to an absence of practice opportunities. The 4-week washout coincided with Christmas school holidays, during which time participants were not engaging in any PE or FMS intervention, and non-school based sport and physical activity opportunities were likely low. Despite also being on school holidays and having not yet received the intervention, FMS scores for Group C-I significantly increased from T2 to T3 which may suggest the presence of a learning effect from repeatedly using the TGMD-3 assessment tool. FMS scores were not assessed 4 weeks after Group C-I completed the intervention. Thus, it is unknown if FMS proficiency levels decreased similar to that of Group I-C after the 4-week wash-out period. This may be worth considering in future studies to gain further insight into the potential non-linear nature of FMS development.

During assessment sessions, children observed both expert (from the demonstrator) and novice (from peers) demonstrations of each skill. Individually, each strategy can support learning (Martens, Burwitz and Zuckerman 1976; Sigmundsson et al. 2017; McMorris 2004); however, combined expert and novice observation has been shown to significantly enhance motor learning compared to observing either an expert or novice alone (Rohbanfard and Proteau 2011). Observational learning can engage similar cognitive processes that occur during physical practice (Blandin, Lhuisset and Proteau 1999). The learner can formulate an ideal movement pattern in their mind from observing an expert, whilst observing a novice performer helps the learner to detect and correct errors in the movement patterns prior to physically attempting the skill him-/herself (Adams 1986). This may explain why Group C-I improved their FMS during the wash-out period (i.e. from T2 to T3). Future intervention studies may consider using a familiarisation session for the FMS assessment procedure, particularly when assessments are conducted over a short period of time.

A limitation of many FMS intervention studies is the absence of follow-up assessments to determine their long-term effectiveness (Lai et al. 2014). Although a follow-up was included in the current study, the lack of a true control group limits the interpretation of the findings. Both groups had higher FMS scores at follow-up compared to baseline, but the improvements cannot be definitively attributed to the intervention programme. Cross-sectional studies looking at differences in FMS proficiency across age give mixed results. Behan et al. (2019) found improvements in FMS scores up to the age of 10 years among Irish primary school children, which might suggest that the follow-up scores observed in the current study may have occurred as part of normal growth and development. In contrast, plateaus in total FMS scores were reported at approximately age 7 and 8 among Belgian (Bardid et al. 2016) and Irish (Kelly et al. 2019) primary school children, respectively. The current sample were 7- to 8-years old at baseline and aged 8- to 9-years old at follow-up, thus the findings of Kelly et al. (2019) and Bardid et al. (2016) suggest that the improvements may not have occurred in the absence of specialist instruction and practice opportunities provided during the FMS intervention programme. Furthermore, studies by Robinson and Goodway (2009), Valentini and Rudisill (2004) and Robinson et al. (2017), previously noted how mastery-oriented instructional climates that aimed to improve FMS proficiency among pre-school aged children consistently facilitated immediate improvements in FMS proficiency, but evidence for sustained improvements were mixed. Whilst Valentini and Rudisill (2004) reported sustained improvements at 6-month follow-up compared to post-intervention scores, children in the other two studies had significantly lower FMS scores at 9-week follow-up compared to their post-intervention scores. The inconsistent results may be due to the varying characteristics of the participants (i.e. children in two studies were classed as developmentally delayed and were also younger than children in the current study sample), and the length of time between post-intervention and follow-up assessments (i.e. 9-weeks and 6-months post-intervention compared to 13-months in the current study).

The concept of assessing FMS learning is difficult due to the non-linear nature of skill acquisition and the multiple personal, environmental and task related factors that may impact a performance at a given moment (Newell 1986). The changes in mastery/near mastery levels for the individual skills highlights this difficulty. Despite each class group receiving the same intervention over the two 8-week intervention phases, differences were observed in relation to the specific skills that improved over time. It also provides evidence for the individual nature of motor learning (Clarke and Metcalfe, 2002) and the fact that there is no one size fits all approach to teaching FMS. The variation in FMS improvements could be interpreted as one of the strengths of adopting a mastery-oriented instructional climate, as it allows each individual to take control of his/her learning experience (Ames 1992). Perhaps the skills that improved were perceived as being more important to one group compared to another. Future studies should aim to understand the factors that contribute to variations in skill improvements by including the learners' perception of what skills they perceive to be important and why.

Previous research highlights that overweight children (Rodrigues et al., 2016; Lima et al. 2018; D'Hondt et al. 2013) and females (Coppens et al. 2019) are less likely to improve their motor competence over time compared to non-overweight children and males, respectively. FMS proficiency is a sub-component of motor competence, thus it was important to determine if those 'at risk' children benefited from participating in the current intervention programme. Similar rates of improvement were observed for participants regardless of their weight status or sex; however, consistent with previous research, we found that males remained significantly better than females in performing object-control skills (Bolger et al. 2018; Kelly et al. 2019; Behan et al. 2019) whilst non-overweight children were consistently more proficient than overweight children at locomotor skills (Kelly et al. 2019; Cliff et al. 2012).

The current results suggest that delivering interventions through a mastery-oriented climate as opposed to an ego-oriented climate may support children of all abilities to experience success and to improve their FMS proficiency at an individualistic and developmentally appropriate rate (García-González et al. 2019). Given that females continued to demonstrate poorer object-control skill proficiency than males across all five time points, future research may consider whether a gender-specific approach to FMS instruction could eliminate this divide. Additionally, a low level of perceived competence is often mentioned as a barrier to physical activity and sport participation among females (Woods et al. 2010; Mitchell, Gray and Inchley 2015) and overweight children (Morrison et al. 2018). Thus, the inclusion of measures of perceived competence would offer valuable insight into the effectiveness of future intervention programmes. Finally, it is important to mention that although the participants had better FMS proficiency at follow-up compared to baseline, the proportion of children classified as overweight or obese at follow-up increased by 7% (i.e. 28% at follow-up versus 21% at baseline). Obesity is a complex issue and can be affected by diet, genetics, activity levels, socio-cultural factors and psychological factors (Sahoo et al. 2015). Thus, although both overweight and non-overweight participants significantly improved their FMS following the intervention, when weight-maintenance or weight-loss is the goal, additional measures to those that facilitate FMS development must be considered.

The present intervention programme was delivered in an ideal situation where the instructor had specialist FMS knowledge and an understanding of mastery-motivational theory. However, many primary school teachers in Ireland have received limited training for teaching PE (Fletcher and Mandigo 2012) and, therefore, may not have the pre-requisite theoretical knowledge that was used to inform this intervention. Previous studies already indicated that teachers can be upskilled to improve the quality of their PE lessons and consequently the FMS proficiency levels of their class group (Rudisill and Johnson 2018). Aiming to determine the role of specialist instruction on FMS proficiency levels, this study acts as a steppingstone to identifying the most appropriate strategies that should be undertaken to improve the quality of

PE teaching within the primary school setting. The findings suggest that specialist knowledge is important to support FMS development. However, it is unknown if generalist teachers are willing to upskill to improve the quality of their PE lessons or if they would prefer to employ PE specialists to either solely teach PE or work alongside them as a means of improving their PE teaching ability. These factors and their feasibility should be addressed in future studies.

Study strengths and limitations

This study has some strengths and limitations. The inclusion of older children (i.e. aged 7-8 years at baseline) is novel and fills a gap in the literature as, to the authors' knowledge, previous studies with similar aims were conducted in pre-school settings (i.e. aged 3-5 years.). As all groups received the FMS intervention programme, it helped to avoid bleed-over and contamination. Additionally, the longitudinal design and inclusion of a 13-month follow-up provided a more comprehensive analysis of FMS development over time. However, limitations include the lack of a true control group at follow-up and the absence of information about what was covered in typical PE lessons, which prevents an accurate interpretation of the long-term effectiveness of the intervention. Although a large number of skills were assessed, none specifically assessed the stability division of FMS. Balance is an underlying requirement to efficiently execute many locomotor and object-control skills; however, future studies could be strengthened by assessing balance or stability skills separately. Additionally, there was a risk of bias in scoring the FMS, as the principal investigator was not blinded to participant allocation. The number of children with mild learning disabilities was not recorded and may also be seen as a limitation. Lesson fidelity was not recorded during the study; however, the principal investigator delivered all lessons to all class groups allowing for consistency throughout the study. The findings may not be generalisable to the national and international primary education settings as the intervention was delivered in ideal circumstances by an instructor with specialist FMS knowledge and an understanding of how to facilitate a mastery-motivational climate. Future research should aim to determine the fidelity and feasibility of upskilling teachers to deliver PE lessons using the concepts undertaken in the current study.

Conclusion

The results of this study suggest that a short-duration FMS intervention, focusing on specialist FMS instruction in a mastery-motivational climate, can significantly improve locomotor and ball skills at post-intervention. The long-term effectiveness is inconclusive and warrants further investigation. Typical primary school PE classes include children with a range of skill levels, interests and abilities, thus maximising engagement by all children is essential to ensure each child is provided with an equal opportunity to experience success. This may be possible when PE lessons are taught by teachers with both specialist FMS knowledge and an understanding of how to create a mastery-motivational climate as regular incentive may be needed for children to attain adequate long-term FMS improvements.

Conflict of interest

The authors declare no conflict of interest for this study.

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Figure Legends

Figure 1: Participant recruitment (n values refer to those who have full TGMD-3 data).

Note: **I-C:** Intervention-control group, **C-I:** Control-intervention group, **T1:** Pre phase 1, **T2:** Post phase 1, **T3:** Pre phase 2, **T4:** Post phase 2, **T5:** Follow-up (i.e. 13-months post-intervention).

Table 1: Baseline characteristics of study participants.

Note: Data is presented as mean ± standard deviation, [a] : Some missing data due to either a. participant decision not to do skill, b. participant joking around or c. problems with recording, **I-C:** Intervention-control group, **C-I:** Control-intervention group, **% OW-OB:** % Overweight-obese, **% Non-OW:** % Non-overweight, **%m/nm/pm:** % Mastery/near-mastery/poor mastery where mastery = correct performance of all skill criteria over two trials, near-mastery = correct performance of all but one skill criteria over two trials, and poor mastery = incorrect performance or absence of more than one criteria over two trials **H jump:** Horizontal jump, **FHS:** Forehand strike, **OHT:** Overhand throw, **UHT:** Underhand throw, **LM:** Locomotor, **BS:** Ball skill, **FMS**: Fundamental movement skill.

Figure 2: Within group and between group changes in locomotor subtest scores for phase 1, phase 2 and follow-up.

Note: **a:** Within group change for phase 1, **b:** Within group change for phase 2, **c:** Within group change from baseline to follow-up, **d:** Adjusted mean difference (**AMD**) and 95% CI; results from linear mixed model with random effect for class group, **e:** Group-time interaction from mixed model with class group as random effect, **f:** Adjusted mean difference and 95% CI between each respective I-C and C-I group (I-C minus C-I); results from linear mixed model with random effect for class group, **I-C:** Intervention-control group, **C-I:** Control-intervention group, **ES:** Effect size (Cohen's d), **T1:** Pre phase 1, **T2:** Post phase 1, **T3:** Pre phase 2, **T4:** Post phase 2, **T5:** 13-months post-intervention.

Figure 3: Within group and between group changes in ball skills subtest scores for phase 1, phase 2 and follow-up.

Note: **a:** Within group change for phase 1, **b:** Within group change for phase 2, **c:** Within group change from baseline to follow-up, **d:** Adjusted mean difference (**AMD**) and 95% CI; results from linear mixed model with random effect for class group, **e:** Group-time interaction from mixed model with class group as random effect, **f:** Adjusted mean difference and 95% CI between each respective I-C and C-I group (I-C minus C-I); results from linear mixed model with random effect for class group, **I-C:** Intervention-control group, **C-I:** Control-intervention group, **ES:** Effect size (Cohen's d), **T1:** Pre phase 1, **T2:** Post phase 1, **T3:** Pre phase 2, **T4:** Post phase 2, **T5:** 13-months post-intervention.

Figure 4: Within group and between group changes in Total FMS scores for phase 1, phase 2 and follow-up.

Note: **a:** Within group change for phase 1, **b:** Within group change for phase 2, **c:** Within group change from baseline to follow-up, **d:** Adjusted mean difference (**AMD**) and 95% CI; results from linear mixed model with random effect for class group, **e:** Group-time interaction from mixed model with class group as random effect, **f:** Adjusted mean difference and 95% CI between each respective I-C and C-I group (I-C minus C-I); results from linear mixed model with random effect for class group, **I-C:** Intervention-control group, **C-I:** Control-intervention group, **ES:** Effect size (Cohen's d), **T1:** Pre phase 1, **T2:** Post phase 1, **T3:** Pre phase 2, **T4:** Post phase 2, **T5:** 13-months post-intervention.

Table 2: Percentage change and actual percentage achieving mastery/near mastery and poor mastery in each skill for phase 1 and phase 2 for each group.

Note: **I-C:** Intervention-control group, **C-I:** Control-intervention group, **MNM**: Mastery/near mastery, **PM:** Poor mastery, **a**: Proportion of participants who change from MNM to PM, **b**: Proportion of participants who change from PM to MNM **c**: Actual % of participants who display MNM, **T1:** Pre phase 1, **T2:** Post phase 1, **T3:** Pre phase 2, **T4:** Post phase 2, † Represents percentage change from McNemar test, **OR:** Odds ratio, **H jump:** Horizontal jump, **FHS:** Forehand strike, **OHT:** Overhand throw, **UHT:** Underhand throw.

Table 3: Percentage change and actual percentage achieving mastery/near mastery and poor mastery for all participants from baseline to follow-up.

Note: **MNM**: Mastery/near mastery, **PM:** Poor mastery, **a:** Proportion of participants who change from MNM to PM from baseline to follow-up, **b**: Proportion of participants who change from PM to MNM from baseline to follow-up, **c**: Actual % of participants who display MNM at baseline/follow-up, †Represents percentage change from McNemar test, **FU:** Follow-up, **H jump:** Horizontal jump, **FHS:** Forehand strike, **OHT:** Overhand throw, **UHT:** Underhand throw.

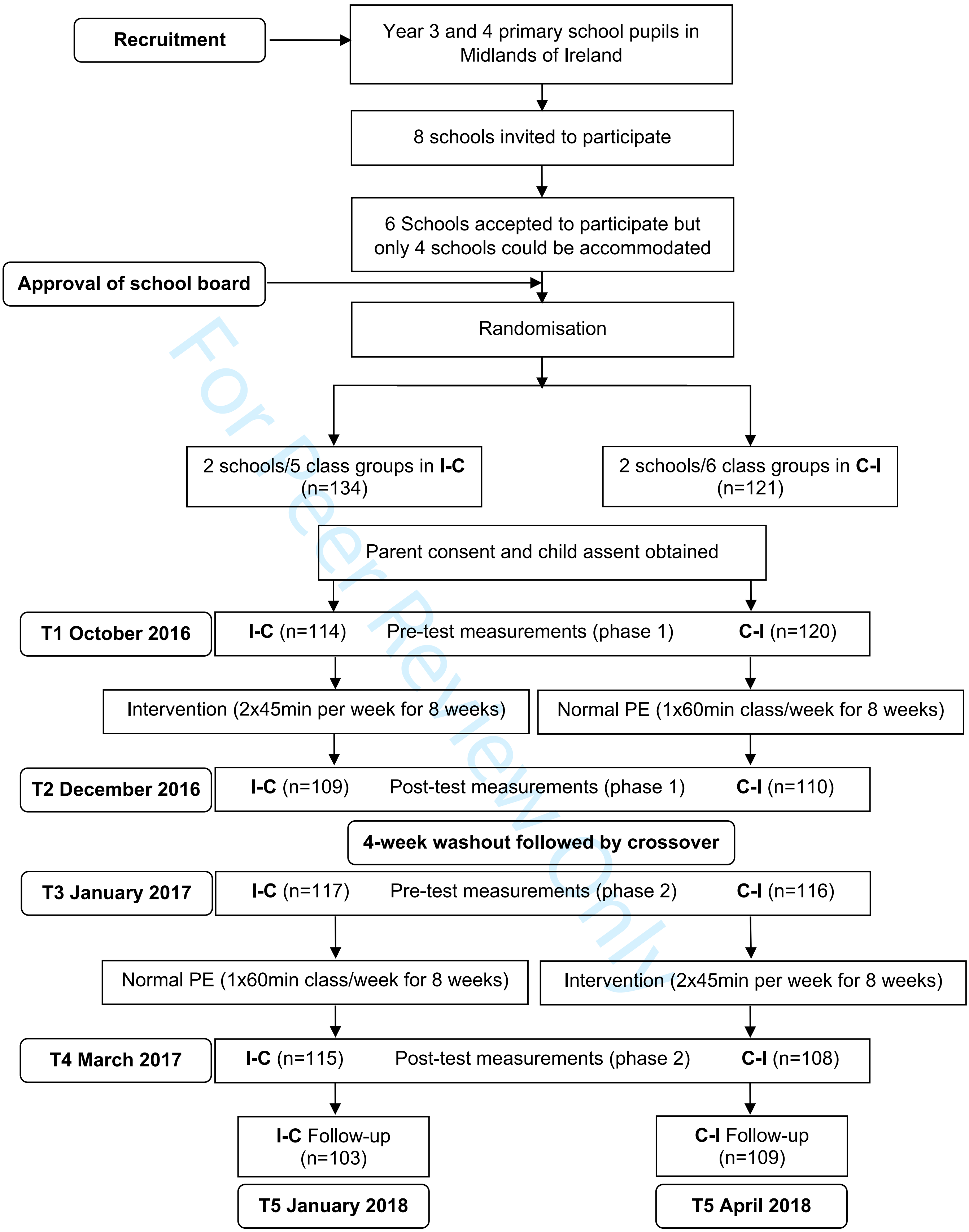


Figure 1 Participant recruitment (n values refer to those who have full TGMD-3 data).

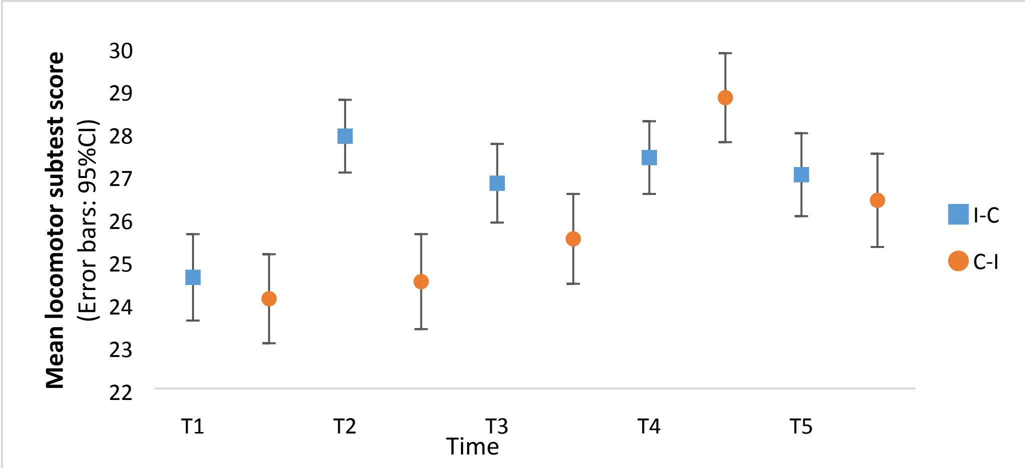
Note: **I-C:** Intervention-control group, **C-I:** Control-intervention group, **T1:** Pre phase 1, **T2:** Post phase 1, **T3:** Pre phase 2, **T4:** Post phase 2, **T5:** Follow-up (i.e. 13-months post-intervention).

Table 1 Baseline characteristics of study participants.

Variable	Total			Group I-C			Group C-I		
	All (N=255)	**Male (n=127)**	**Female (n=128)**	**All (n=134)**	**Male (n=64)**	**Female (n=70)**	**All (n=121)**	**Male (n=63)**	**Female (n=58)**
Age (years)	7.4±0.6	7.5±0.6	7.4±0.7	7.5±0.7	7.5±0.7	7.4±0.7	7.4±0.6	7.5±0.6	7.3±0.6
Mass (kg)	26.2±5.8	26.6±5.7	25.7±5.8	26.6±6.3	26.9±6.1	26.2±6.4	25.8±5.2	26.3±5.3	25.2±5.1
Height (cm)	125.4±6.2	125.9±6.0	124.9±6.4	125.8±6.8	126.7±6.2	125.1±5.6	124.9±5.4	125.1±5.6	124.7±5.3
% OW-OB/Non-OW	21/79	21/79	20/80	22/78	23/77	21/79	19/81	19/81	19/81
Run n=241 [a] (% m/nm/pm)	4.3±1.8 (6/16/77)	4.1±1.7 (4/16/80)	4.4±1.8 (9/19/72)	4.4±1.8 (6/23/71)	4.3±1.7 (5/21/74)	4.5±1.8 (6/25/69)	4.1±1.8 (7/12/81)	3.9±1.7 (3/11/86)	4.4±1.9 (12/12/76)
Gallop n=250 [a] (% m/nm/pm)	3.1±2.0 (0/14/86)	3.1±2.1 (0/15/85)	3.1±2.0 (0/14/86)	3.0±2.0 (0/12/88)	3.2±2.1 (0/16/84)	2.8±2.0 (0/7/93)	3.2±2.1 (0/18/82)	3.0±2.1 (0/13/87)	3.4±2.0 (0/22/78)
Hop n=240 [a] (% m/nm/pm)	3.4±1.6 (1/8/91)	3.3±1.5 (1/6/93)	3.6±1.6 (2/11/87)	3.5±1.7 (3/9/88)	3.3±1.7 (2/7/91)	3.7±1.7 (3/11/14)	3.4±1.4 (0/7/93)	3.2±1.4 (0/5/95)	3.5±1.4 (0/10/90)
Skip n=240 [a] (% m/nm/pm)	3.2±1.4 (1/65/34)	3.0±1.4 (0/63/37)	3.4±1.3 (1/66/33)	3.4±1.3 (1/73/26)	3.2±1.4 (0/69/31)	3.6±1.1 (2/77/21)	3.0±1.5 (0/65/35)	2.9±1.4 (0/56/44)	3.2±1.4 (0/74/26)
Slide n=240 [a] (% m/nm/pm)	5.7±2.0 (28/27/45)	5.7±2.1 (31/21/48)	5.7±2.0 (25/32/43)	5.6±1.9 (24/27/49)	5.6±2.2 (32/17/51)	5.6±1.7 (30/25/45)	5.7±2.1 (31/26/43)	5.8±2.0 (30/25/45)	5.7±2.2 (33/28/39)
H jump n=254 [a] (% m/nm/pm)	4.5±1.6 (4/25/71)	4.6±1.7 (5/27/68)	4.4±1.5 (3/23/74)	4.4±1.4 (1/24/75)	4.5±1.4 (0/30/70)	4.4±1.3 (1/19/80)	4.5±1.9 (8/26/66)	4.6±2.0 (10/34/56)	4.4±1.8 (5/28/67)
Strike n=255 (% m/nm/pm)	5.8±1.8 (2/17/81)	6.3±1.9 (4/21/75)	5.4±1.7 (0/13/87)	6.1±1.9 (4/22/74)	6.5±2.0 (8/23/69)	5.8±1.8 (0/21/79)	5.5±1.6 (0/12/88)	6.1±1.6 (0/19/81)	4.9±1.4 (0/3/97)
FHS n=255 (% m/nm/pm)	3.3±2.2 (3/15/82)	3.9±2.3 (5/21/74)	2.7±1.9 (1/9/90)	3.2±2.2 (2/15/83)	3.8±2.3 (5/19/76)	2.6±2.0 (0/11/89)	3.4±2.2 (3/15/82)	4.0±2.3 (5/24/71)	2.7±1.8 (2/5/93)

OHT n=254 [a] (% m/nm/pm)	3.9±1.9 (7/14/79)	4.3±2.1 (10/19/71)	3.4±1.7 (3/9/88)	4.4±1.9 (9/19/72)	4.9±1.9 (13/25/62)	3.8±1.8 (6/13/81)	3.3±1.8 (4/9/87)	3.6±2.1 (8/13/79)	3.0±1.4 (0/5/95)
UHT n=254 [a] (% m/nm/pm)	5.3±1.6 (11/36/53)	5.2±1.6 (9/32/59)	5.3±1.6 (12/39/49)	5.3±1.6 (10/41/49)	5.1±1.6 (8/34/58)	5.5±1.5 (12/46/42)	5.2±1.7 (12/31/57)	5.3±1.6 (11/30/59)	5.1±1.7 (12/31/57)
Kick n=255 (% m/nm/pm)	3.8±1.6 (3/13/84)	4.5±1.8 (6/23/71)	3.1±1.2 (0/3/97)	3.6±1.6 (2/11/87)	4.4±1.7 (5/22/73)	2.9±1.1 (0/1/99)	4.0±1.7 (4/15/81)	4.6±1.8 (8/24/68)	3.4±1.2 (0/5/95)
Dribble n=254 [a] (% m/nm/pm)	3.3±1.7 (11/34/55)	3.5±1.7 (15/35/50)	3.0±1.7 (7/32/61)	3.2±1.7 (12/29/59)	3.6±1.7 (19/30/51)	2.8±1.8 (6/28/66)	3.3±1.7 (10/39/51)	3.4±1.7 (11/40/49)	3.2±1.6 (9/38/53)
Catch n=255 (% m/nm/pm)	4.0±1.4 (18/43/39)	3.9±1.3 (15/48/37)	4.0±1.4 (21/38/41)	4.0±1.3 (16/46/38)	4.0±1.3 (17/48/35)	3.9±1.3 (14/44/42)	4.0±1.4 (21/39/40)	3.9±1.3 (13/48/39)	4.2±1.5 (29/29/42)
LM subtest (n=234)	24.3±5.6	23.8±5.5	24.8±5.6	24.6±5.4	24.3±5.7	24.8±5.3	24.1±5.7	23.4±5.4	24.7±6.0
BS subtest (n=252)	29.4±6.5	31.7±6.8	27.1±5.2	29.9±6.8	32.5±6.9	27.6±5.7	28.8±6.2	30.9±6.7	26.5±4.6
Total FMS (n=234)	53.6±9.8	55.6±10.6	51.7±8.7	54.5±9.9	57.4±10.7	52.1±8.5	52.8±9.7	54.2±10.3	51.3±8.9

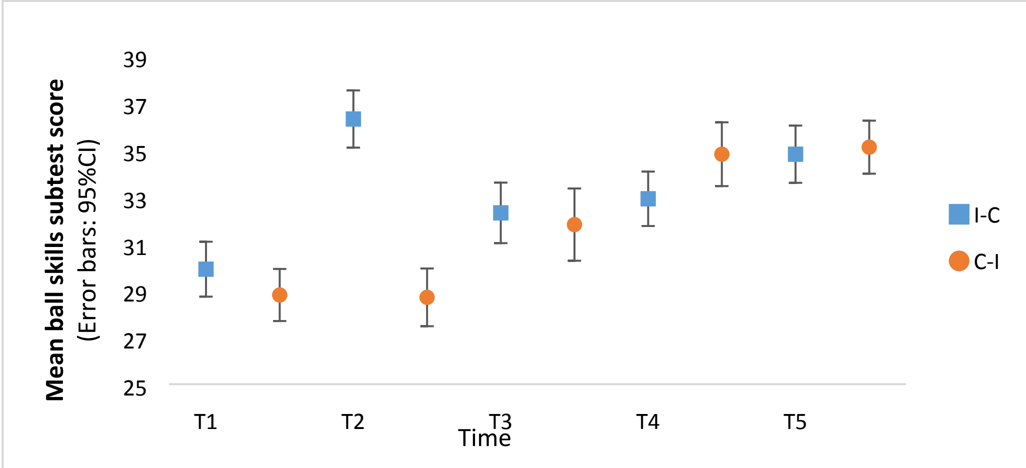
Note: Data is presented as mean ± standard deviation, [a] : Some missing data due to either a. participant decision not to do skill, b. participant joking around or c. problems with recording, **I-C:** Intervention-control group, **C-I:** Control-intervention group, **% OW-OB:** % Overweight-obese, **% Non-OW:** % Non-overweight, **%m/nm/pm:** % Mastery/near-mastery/poor mastery where mastery = correct performance of all skill criteria over two trials, near-mastery = correct performance of all but one skill criteria over two trials, and poor mastery = incorrect performance or absence of more than one criteria over two trials **H jump:** Horizontal jump, **FHS:** Forehand strike, **OHT:** Overhand throw, **UHT:** Underhand throw, **LM:** Locomotor, **BS:** Ball skill, **FMS**: Fundamental movement skill.



Group	Phase 1: Within group change					Phase 2: Within group change					Follow-up: Within group change from baseline			
	T1 Mean (SD)	**T2 Mean (SD)**	***p*** [a]	**AMD (95% CI)**[d]	**ES**	**T3 Mean (SD)**	**T4 Mean (SD)**	***p*** [b]	**AMD (95% CI)**[d]	**ES**	**T5 Mean (SD)**	***p*** [c]	**AMD (95% CI)**[d]	**ES**
I-C	24.6 (5.4)	27.9 (4.6)	<0.001	-3.3 (-4.7, -1.9)	0.6	26.8 (5.1)	27.4 (4.6)	1.00	-0.3 (-1.4, 0.8)	0.1	27.0 (5.3)	0.02	-1.7 (-3.3, -0.2)	0.4
C-I	24.1 (5.7)	24.5 (5.9)	1.00	-0.4 (-1.8, 1.0)	0.1	25.5 (5.7)	28.8 (5.5)	<0.001	-3.2 (-4.3, -2.1)	0.6	26.4 (5.9)	<0.001	-2.5 (-3.9, -1.0)	0.4
Between group differences (I-C minus C-I)														
	T1	**T2**				**T3**	**T4**				**T5**			
p [e]	0.61	<0.001				0.08	0.01				0.60			
ES	0.1	0.6				0.2	0.3				0.1			
AMD (95% CI)[f]	0.4 (-1.0, 1.8)	3.3 (2.0, 4.6)				1.2 (-0.1, 2.5)	-1.7 (-3.0, -0.4)				-0.4 (-1.7, 1.0)			

Figure 2: Within group and between group changes in locomotor subtest scores for phase 1, phase 2 and follow-up.

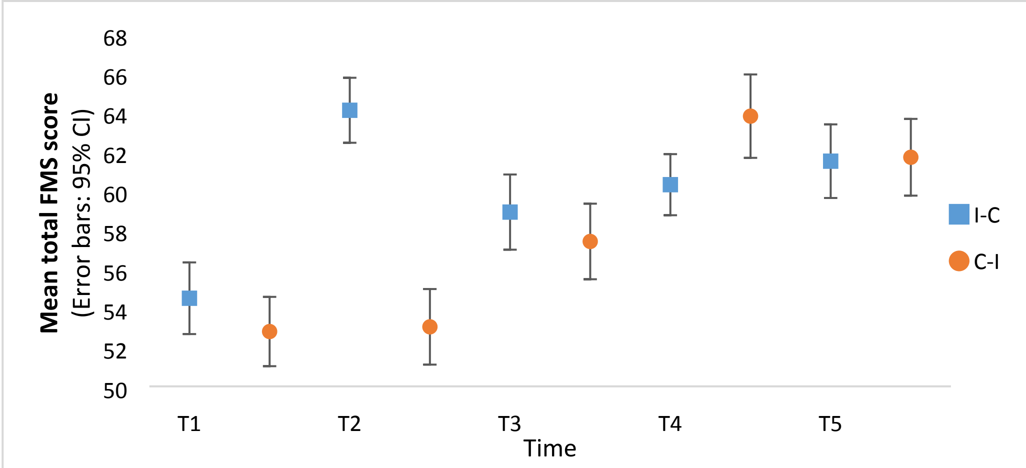
Note: **a:** Within group change for phase 1, **b:** Within group change for phase 2, **c:** Within group change from baseline to follow-up, **d:** Adjusted mean difference (**AMD**) and 95% CI; results from linear mixed model with random effect for class group, **e:** Group-time interaction from mixed model with class group as random effect, **f:** Adjusted mean difference and 95% CI between each respective I-C and C-I group (I-C minus C-I); results from linear mixed model with random effect for class group, **I-C:** Intervention-control group, **C-I:** Control-intervention group, **ES:** Effect size (Cohen's d), **T1:** Pre phase 1, **T2:** Post phase 1, **T3:** Pre phase 2, **T4:** Post phase 2, **T5:** 13-months post-intervention.



Group	Phase 1: Within group change					Phase 2: Within group change					Follow-up: Within group change from baseline			
	T1 Mean (SD)	T2 Mean (SD)	p [a]	AMD (95% CI)[d]	ES	T3 Mean (SD)	T4 Mean (SD)	p [b]	AMD (95% CI)[d]	ES	T5 Mean (SD)	p [c]	AMD (95% CI)[d]	ES
I-C	29.9 (6.8)	36.3 (6.5)	<0.001	-6.4 (-7.8, -5.0)	1.0	32.3 (7.1)	32.9 (6.4)	1.0	-0.2 (-1.7, 1.1)	0.1	34.8 (6.7)	<0.001	-4.8 (-6.3, -3.2)	0.7
C-I	28.8 (6.2)	28.7 (6.6)	1.00	-0.0 (-1.4, 1.4)	0.0	31.8 (6.7)	34.8 (7.2)	<0.001	-3.2 (-4.6, -1.7)	0.4	35.1 (6.1)	<0.001	-6.2 (-7.8, -4.7)	1.0
Between group differences (I-C minus C-I)														
	T1	**T2**				**T3**	**T4**				**T5**			
p [e]	0.21	<0.001				0.44	0.01				0.59			
ES	0.2	1.2				0.1	0.3				0.1			
AMD (95% CI)[f]	1.0 (-0.6, 2.6)	7.4 (5.8, 9.1)				0.67 (-1.0, 2.4)	-2.2 (-3.9, -0.5)				-0.4 (-2.0, 1.2)			

Figure 3: Within group and between group changes in object-control subtest scores for phase 1, phase 2 and follow-up.

Note: **a:** Within group change for phase 1, **b:** Within group change for phase 2, **c:** Within group change from baseline to follow-up, **d:** Adjusted mean difference (**AMD**) and 95% CI; results from linear mixed model with random effect for class group, **e:** Group-time interaction from mixed model with class group as random effect, **f:** Adjusted mean difference and 95% CI between each respective I-C and C-I group (I-C minus C-I); results from linear mixed model with random effect for class group, **I-C:** Intervention-control group, **C-I:** Control-intervention group, **ES:** Effect size (Cohen's d), **T1:** Pre phase 1, **T2:** Post phase 1, **T3:** Pre phase 2, **T4:** Post phase 2, **T5:** 13-months post-intervention.



Group	Phase 1: Within group change					Phase 2: Within group change					Follow-up: Within group change from baseline			
	T1 Mean (SD)	T2 Mean (SD)	*p* [a]	AMD (95% CI)[d]	ES	T3 Mean (SD)	T4 Mean (SD)	*p* [b]	AMD (95% CI)[d]	ES	T5 Mean (SD)	*p* [c]	AMD (95% CI)[d]	ES
I-C	54.5 (9.9)	64.1 (8.8)	<0.001	-9.5 (-11.6, -7.3)	1.0	59.0 (10.5)	60.3 (8.4)	1.00	-0.6 (-2.4, 1.2)	0.1	61.5 (9.6)	<0.001	-6.2 (-8.6, -3.9)	0.7
C-I	52.8 (9.7)	53.0 (10.2)	1.00	-0.3 (-2.4, 1.8)	0.0	57.4 (10.5)	63.8 (11.2)	<0.001	-6.4 (-8.1, -4.6)	0.6	61.7 (10.3)	<0.001	-8.7 (-10.9, -6.4)	0.9
Between group differences (I-C minus C-I)														
	T1	**T2**				**T3**	**T4**				**T5**			
p [e]	0.20	<0.001				0.19	0.001				0.49			
ES	0.2	1.2				0.1	0.3				0.0			
AMD (95% CI)[f]	1.6 (-0.8, 4.0)	10.7 (8.3, 13.1)				1.7 (-0.8, 4.3)	-4.0 (-6.4, -1.6)				-0.8 (-3.4, 1.6)			

Figure 4: Within group and between group changes in total FMS scores for phase 1, phase 2 and follow-up.

Note: **a:** Within group change for phase 1, **b:** Within group change for phase 2, **c:** Within group change from baseline to follow-up, **d:** Adjusted mean difference (**AMD**) and 95% CI; results from linear mixed model with random effect for class group, **e:** Group-time interaction from mixed model with class group as random effect, **f:** Adjusted mean difference and 95% CI between each respective I-C and C-I group (I-C minus C-I); results from linear mixed model with random effect for class group, **I-C:** Intervention-control group, **C-I:** Control-intervention group, **ES:** Effect size (Cohen's d), **T1:** Pre phase 1, **T2:** Post phase 1, **T3:** Pre phase 2, **T4:** Post phase 2, **T5:** 13-months post-intervention.

Table 2 Percentage change and actual percentage achieving mastery/near mastery and poor mastery in each skill for phase 1 and phase 2 for each group.

	Phase 1 (T1 vs T2)							Phase 2 (T3 vs T4)						
Skill/ Group	n	%MNM – PM [a]	%PM – MNM [b]	%MNM T1/T2 [c]	p[†]	Chi-square	OR	n	%MNM - PM [a]	%PM – MNM [b]	%MNM T3/T4 [c]	p[†]	Chi-square	OR
Run														
I-C	116	11	23	26/37	0.04	4.20	2.09	110	21	15	42/32	0.43	0.62	0.71
C-I	113	13	25.5	19/31	0.04	4.00	1.96	112	12	17	32/36	0.38	0.78	1.42
Gallop														
I-C	112	4	23	11/26	<0.001	14.7	5.75	109	17	15	31/26	0.86	0.03	0.88
C-I	112	11	9	17/15	0.83	0.04	0.82	110	11	27	20/35	0.009	6.88	2.45
Hop														
I-C	114	10	5	10/7	0.33	0.16	0.50	111	10	5	11/7	0.33	0.94	0.50
C-I	112	6	7	7/8	1	0.00	1.17	112	4	16	12/22	0.01	6.26	4.00
Skip														
I-C	114	9	17	66/71	0.14	2.20	1.89	111	12	13	72/71	1	0.00	1.08
C-I	113	9	13	64/64	0.42	0.64	1.45	113	8	23	66/80	0.007	7.31	2.87
Slide														
I-C	114	20	28	45/53	0.28	1.16	1.40	108	11	16	58/58	0.46	0.55	1.45
C-I	113	23	14	58/46	0.16	1.93	0.60	113	3	16	73/83	0.002	9.33	5.33
H jump														
I-C	115	9	29	25/39	0.001	11.25	3.22	111	16	12	23/18	0.47	0.52	0.75
C-I	111	23	10	33/17	0.02	5.29	0.43	112	10	25	25/38	0.01	6.56	2.50
Strike														
I-C	119	14	17	26/27	0.74	0.11	1.21	108	12	19	16/24	0.23	1.44	1.58
C-I	113	8	11	12/12	0.66	0.19	1.37	111	14	22	31/35	0.27	1.22	1.57
FHS														
I-C	117	9	21	17/26	0.04	4.11	2.33	111	9	12	15/18	0.68	0.17	1.33
C-I	113	11.5	4	18/9	0.05	3.76	0.35	112	5	21	12/27	0.002	9.63	4.20
Kick														
I-C	116	2	19	13/26	<0.001	15.04	9.50	111	10	13.5	25/28	0.56	0.35	1.35
C-I	113	4	8	19/22	0.42	0.64	2.00	111	4.5	9	26/29	0.3	1.07	2.00
OHT														
I-C	115	3	28	27/44	<0.001	20.25	9.33	111	22	4.5	35/17	0.001	11.17	0.20
C-I	112	8	3	13/7	0.15	2.08	0.37	112	5	16	14/24	0.02	5.04	3.20

UHT														
I-C	115	4	35	50/70	<0.001	25.69	8.75	111	22	22.5	45/43	1	0.00	1.02
C-I	112	21	26	42/45	0.49	0.48	1.24	111	16	20	59/62	0.63	0.22	1.25
Dribble														
I-C	118	6	35	40/61	<0.001	22.69	5.83	110	15	21	61/65	0.31	0.62	1.40
C-I	113	13	19	49/50	0.4	0.69	1.46	110	5	21	53/65	0.003	8.83	4.20
Catch														
I-C	116	16	13	62/52	0.73	0.12	0.81	110	15	21	49/51	0.43	0.62	1.40
C-I	112	25	18	60/48	0.31	1.02	0.72	112	14	14.5	60/60	1	0.00	1.03

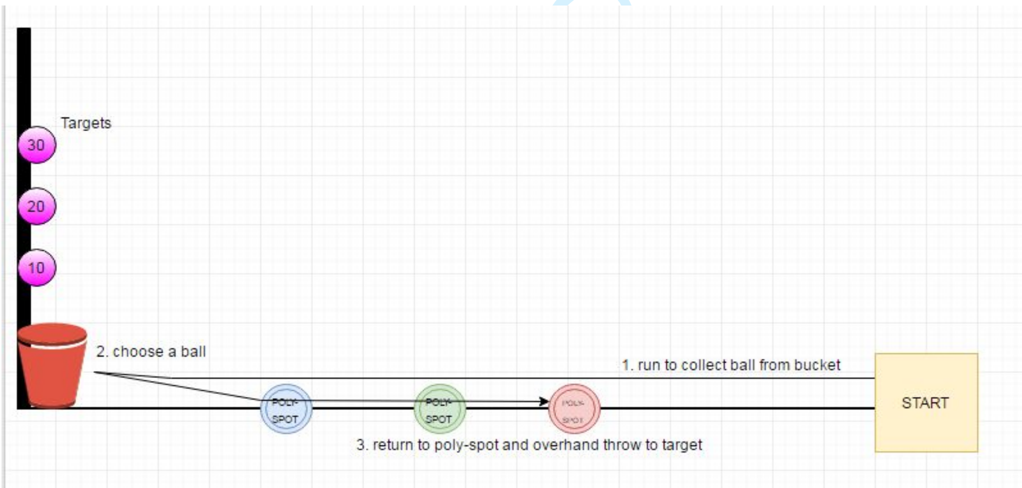
Note: **I-C:** Intervention-control group, **C-I:** Control-intervention group, **MNM**: Mastery/near mastery, **PM:** Poor mastery, **a**: Proportion of participants who change from MNM to PM, **b**: Proportion of participants who change from PM to MNM **c**: Actual % of participants who display MNM, **T1:** Pre phase 1, **T2:** Post phase 1, **T3:** Pre phase 2, **T4:** Post phase 2, † Represents percentage change from McNemar test, **OR:** Odds ratio, **H jump:** Horizontal jump, **FHS:** Forehand strike, **OHT:** Overhand throw, **UHT:** Underhand throw.

Table 3 Percentage change and actual percentage achieving mastery/near mastery and poor mastery for all participants from baseline to follow-up.

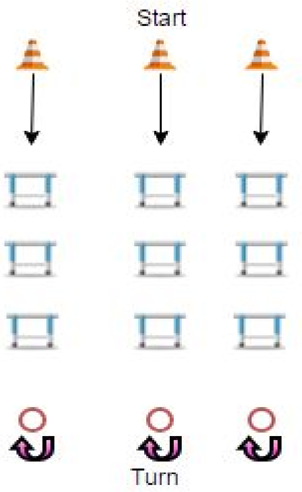
Baseline to follow-up (T1 vs T5)							
Skill	**n**	**%MNM - PM [a]**	**%PM – MNM [b]**	***%MNM* Baseline/FU [c]**	***p*†**	**Chi-Square**	**Odds ratio**
Run	219	12	20	23/29	0.07	3.21	1.67
Gallop	228	11	23	14/26	0.001	10.18	2.09
Hop	220	8	9	9/10	0.87	0.03	1.12
Skip	220	11	23	65/73	0.004	8.22	2.09
Slide	220	14	22	51/60	0.07	3.24	1.57
H jump	229	16	24	29/35	0.05	3.92	1.50
Strike	232	12	29	19/32	<0.001	15.20	2.42
FHS	232	9	22	18/26	0.001	10.12	2.44
Kick	232	4	22	16/31	<0.001	26.23	5.50
OHT	231	14	16	21/21	0.72	0.13	1.14
UHT	231	13	30	46/58	<0.001	14.30	2.31
Dribble	231	6	32	44/65	<0.001	41.38	5.33
Catch	232	14	25	61/68	0.008	6.94	1.78

Note: **MNM**: Mastery/near mastery, **PM:** Poor mastery, **a:** Proportion of participants who change from MNM to PM from baseline to follow-up, **b**: Proportion of participants who change from PM to MNM from baseline to follow-up, **c**: Actual % of participants who display MNM at baseline/follow-up, †Represents percentage change from McNemar test, **FU:** Follow-up, **H jump:** Horizontal jump, **FHS:** Forehand strike, **OHT:** Overhand throw, **UHT:** Underhand throw.

Session 9
Skills: Throw, catch, gallop

Warm up 10 minutes	Zombie Tag Two players are given bibs and one player given a soft ball. The bibs are the taggers. If someone gets tagged, they walk around like a zombie. The player with the ball can free the zombies by touching them with the ball. Start with running, then have children gallop or skip for other rounds. Progress to incorporating throwing and catching. The person with the ball can only free the zombie if they execute a clean throw and catch. Dynamic Stretch
Activity 1 **Equipment:** Cones Variety of balls Baskets	**Overhand throw:** Target throw Two teams line up Place targets on the wall with points allocated to each target Leave bucket of ball beside at the end of the hall Players must run to the bucket, choose a ball of choice return to a poly-spot of their choice and aim for a target. (Change method of movement to collect ball. E.g. gallop, skip etc. Each team adds up their score as they go along After a player throws they must collect their ball and pass it to the next player who will then return it to the bucket and choose a different ball. • Encourage good technique for running/galloping out • Pay attention to use of arms • Encourage players to challenge themselves (don't always choose the closest marker) • Watch for step forward with opposite foot • Side on stance • Follow through 

Session 9
Skills: Throw, catch, gallop

Activity 2 **Equipment:** Hurdles Cones Poly-spots Small balls/beanbags	**Horserace relays** **<u>Set up:</u>** 3 cones (1 for each team) 3 hurdles for each team Teams line up behind their cones The aim is to take it in turns galloping from the start cone to the end cone and jump the hurdles on the way. 
Activity 3 **Equipment:** Hurdles Cones Poly-spots Small balls/beanbags Baskets	**<u>Set up:</u>** **As above only take away the first hurdle and place a poly-spot in its place** **Place a bucket with small balls and beanbags at the end zone for each team** **Place a basket at the start line for each team** Players must gallop out, jumping hurdles along the way to their bucket. They can choose any ball/beanbag, gallop back to the poly-spot and then underhand throw to the next team member. The ball can only be put in the basket if caught cleanly. Players keep trying until the ball is caught, after which the next player goes.
Cool Down 5 minutes	Gentle jog and stretch
Total 45 minutes	

Session 9
Skills: Throw, catch, gallop

Theoretical influence of how the intervention was delivered

Achievement Goal Theory (Nicholls, 1986) and Self-determination theory (Deci and Ryan, 2008) guided the pedagogical approach for the intervention. Achievement Goal Theory proposes that learners are motivated to engage with lessons by either an ego or task/mastery oriented climate. Ego-based climates are characterised by social comparison, external rewards and aiming to be the best with as little effort as possible. Teachers who promote competition and winning and who publicly recognise the best performance within the class are more likely to create an ego-oriented climate. In contrast, mastery-oriented lessons are created by rewarding hard work and effort, focusing on self-improvement and avoiding peer comparison. The TARGET acronym (Ames 1992) was used to guide the principal investigator in facilitating a mastery-motivational climate.

TARGET Component	Description
Task	The tasks in each lesson could be varied to suit different ability levels. Children were encouraged to challenge themselves but were offered choice in terms of the levels of difficulty to work at during any given activity. e.g. an activity that targeted throwing, catching and kicking was created whereby three sets of hurdles were lined up. Each row varied in difficulty based on the height of the hurdle. The children could select what row to practice at. When they felt comfortable at a certain height they were encouraged to try the next difficulty level and so on. Throwing and catching was then incorporated by placing a selection of balls at the end of each row of hurdles. After galloping over the hurdles, a child could select a ball from the bag. On the way back towards their team they could choose a distance from which to throw the selected ball to the next child so that they could catch the ball. After catching the ball cleanly, the next child then galloped with the ball through the hurdles, returned the ball to the bag and finally chose their own ball to throw to their next team mate.
Authority	Authority was seen as a collaboration between the students and the instructor. The instructor was there to act as a facilitator and encourage children to take ownership of their own learning experience. This was achieved by involving the children in setting out rules, giving them some ownership over the length of time to spend on tasks, for example, three main activities were planned for each lesson, however, children could choose to continue with a given task for longer so in some instances two activities were covered in a class rather than three. They were also encouraged to explore different ways of engaging in a task. For example, they weren't told specifically how to throw the ball, but rather asked to think about ways of throwing the ball to make it easier for their teammate to catch it. This often resulted in using an underhand throw. In contrast, for another activity where they were aiming at a target far away, they were more likely to realise that an overhand throw was more efficient.
Recognition	The teacher recognised effort and engagement with tasks and offered feedback and encouragement quietly on an individual basis. Competition, winning and peer comparison were avoided.

Session 9
Skills: Throw, catch, gallop

Grouping	The children could choose who they wanted to work with and were encouraged to change it up throughout lessons.
Evaluation	Evaluation was ongoing for both the instructor and the children. The instructor evaluated things that were and were not working during the lessons and brought that forward to future lessons. Children were encouraged to evaluate their own experiences during certain tasks. Questions were used to stimulate this evaluation such as the throwing example above. I.e. what way would you recommend throwing a ball to make it easier for your partner to catch it and how would you throw the ball if you want to throw it really far. The children were also encouraged to provide supportive feedback to their peers during some tasks in order to figure out ways of helping each other to improve their skills.
Time	Time on task varied according to the needs of individuals and the overall class. Although a lesson plan was created for each lesson, it was designed to target the specific skills in a flexible manner.

Effects of an 8-week school-based intervention programme on Irish school children's fundamental movement skills.

Abstract

Background: Irish school children have demonstrated poor proficiency in fundamental movement skills (FMS) and consistent with international literature, females and overweight children tend to be less skilled than males and non-overweight children. Interventions that are suitable for children of all abilities and which provide long-term improvements in FMS proficiency are warranted.

Purpose: This study examined the immediate and long-term effects of an 8-week FMS intervention programme on 255 Year 3 and 4 Irish school children's (50% male, 7.4±0.6yr) FMS proficiency levels. It was hypothesised that using a mastery motivational climate to deliver the intervention sessions would provide immediate and long-term improvements for all children, including females and overweight children.

Methods: Participants were conveniently recruited from 4 schools and randomly assigned to the intervention-control (Group I-C: 2 schools, n=134, 48% male) or control-intervention (Group C-I: 2 schools, n=121, 52% male) sequence. Group I-C completed the intervention (i.e. two 45-minute FMS classes per week in place of usual PE for 8 weeks) in phase 1, and after a 4-week washout, completed the control condition (i.e. routine PE lessons for 8 weeks) in phase 2, and vice-versa for Group C-I. FMS proficiency, assessed using the Test of Gross Motor Development-Third edition, and weight status based on body mass index (BMI) were recorded at 5 time points: pre and post phase 1, pre and post phase 2 and at 13-months post-intervention (i.e. follow-up).

Results: Linear mixed models revealed significant group × time interaction effects for locomotor, ball skills and total FMS scores (all p<0.001) following engagement in the FMS intervention. No significant changes were observed following engagement in the control condition (i.e. Group C-I: pre to post phase 1 and Group I-C: pre to post phase 2; all p>0.05). Significant improvements for locomotor, ball skills and total FMS scores were reported for both groups at follow-up compared to baseline (all p<0.001). No significant group × time × gender or group × time × weight status interaction effects were reported (all p>0.05). The proportion of participants who improved from poor-mastery to mastery/near-mastery was significant for 8 skills, immediately following the intervention and from baseline to follow-up.

Conclusion: Significant improvements in FMS proficiency were observed following a short-duration intervention that was delivered by an instructor with specialist FMS knowledge and an ability to create a mastery-oriented climate during lessons. Although the long-term effectiveness remains unclear, it is likely that mastery-oriented PE lessons could facilitate greater improvements in FMS development for children of all abilities compared to traditional PE lessons. Future studies should explore if primary teachers feel they have sufficient confidence and pedagogical skills to support children's FMS development during PE.

Keywords: motor competence, physical activity, physical education, weight status, health

Introduction

Fundamental movement skills (FMS) are described as the building blocks of physical activity, and include locomotor (e.g., run, gallop, skip), object-control (e.g., throw, catch, kick) and stability skills (e.g., single leg stance) (Gallahue, Ozmun and Goodway 2012). Achieving proficient levels of FMS is associated with physical and mental health-related benefits including higher levels of physical activity (Holfelder and Schott 2014; Barnett et al., 2011; Laukkanen et al., 2014), maintenance of a healthy weight status (Slotte et al., 2017; Bryant et al., 2014; Southall et al., 2004; O'Brien et al., 2016; Okely et al., 2004; Catuzzo et al. 2016), enhanced physical self-perceptions (Babic et al., 2014), better cognitive function (Draper et al. 2012; van der Fels, et al. 2015) and improved cardiorespiratory fitness (Hardy et al., 2012; Catuzzo et al., 2016).

During early childhood, children need to engage in regular physical activity in order to develop their FMS (Stodden et al. 2008; Robinson et al. 2016). However, only 17% of Irish primary school children are meeting the daily physical activity guidelines (Woods et al. 2018), which indicates that the majority of these children have limited opportunities to develop their skills. Engagement in physical activity and sport declines as children get older, with only 10% of Irish secondary school students meeting the daily physical activity guidelines (Woods et al. 2018). Some of this drop-off could be attributed to inadequate FMS development during the early years (Robinson et al. 2015; Stodden et al. 2008). As children get older and their cognitive awareness improves, they can more accurately perceive their ability to perform skills (Robinson et al. 2015; Babic et al. 2014). Consequently, children with poorer FMS may lose confidence and motivation to continue participating in regular physical activity and sport (Loprinzi, Davis and Fu 2015), which increases their risk of becoming overweight or obese and subsequently developing obesity-related diseases as they get older (Craig et al. 2008; Freedman et al. 2001).

Despite having the potential to master most FMS by the age of 6 years (Gallahue, Ozmun and Goodway 2012), over 50% of Irish primary school children (Bolger et al. 2018; Kelly et al. 2019; Behan et al. 2019) and secondary school adolescents (O'Brien, Belton and Issartel 2016; Lester et al. 2017) are not mastering many FMS. Furthermore, females generally display poorer object-control skill proficiency than males (Behan et al. 2019; O'Brien et al. 2016, Bolger et al. 2018; Hardy et al. 2010; van Beurden et al. 2003) and overweight children demonstrate inferior locomotor and object-control skill proficiency than their non-overweight peers (Hume et al., 2008; Bryant et al., 2014; Morano et al., 2011; Slotte et al., 2015; Catuzzo et al., 2016). Given that the ideal window of opportunity for developing FMS is proposed to be between 3- and 8-years old (Gallahue, Ozmun and Goodway 2012; Clark 2005), FMS interventions should be implemented during early primary school years.

The Test of Gross Motor Development (TGMD) editions 1, 2 and 3 are commonly used process-oriented assessment tools to measure children's FMS proficiency and development (Hulteen et al. 2020; Logan et al. 2018). Skill performances are observed and scored based on the presence or absence of pre-determined criteria to assess movement quality (i.e. the throwing technique) rather than movement outcome (i.e. how far one can throw) (Ulrich 2000; Bardid et al. 2019). In addition to raw scores, categorical variables can be created to classify skill performances by mastery level (i.e. mastery/near mastery or poor mastery) (Hands 2002). Both methods are commonly used to evaluate the effectiveness of school-based FMS interventions, where the mean raw values track changes in subtest scores and mastery categories monitor changes across individual skills (O'Brien et al. 2016; Bolger et al., 2018). As opposed to product-oriented assessments, process-oriented assessments are less influenced by biological factors like strength and size and are thus useful to compare FMS performances by sex and weight status (Haywood, Roberton and Getchell 2012).

Quality instruction and feedback opportunities are essential for FMS development (Gallahue, Ozmun and Goodway 2012; Morgan et al. 2013; Chan et al. 2016; Robinson et al. 2012) with much evidence highlighting the benefits of pedagogical practices that emphasise a mastery-oriented climate to enhance intrinsic motivation (Standage, Duda and Ntoumanis, 2003) and maximise students' engagement in (Solmon 1996) and enjoyment of PE lessons (Vasconcellos et al. 2019; Ntoumanis and Biddle 1999). A mastery-motivational climate can be achieved by ensuring the learner's basic needs of competence, autonomy and relatedness are met during lessons. Short-duration interventions emphasising a mastery-motivational climate have led to significant improvements in FMS proficiency among pre-school aged children, compared to non-mastery climates (Wick et al., 2017; Robinson and Goodway 2009; Valentini and Rudisill, 2004). In the study by Valentini and Rudisill (2004), improvements in FMS were maintained at 6-month follow-up compared to post-intervention scores; however, Robinson and Goodway (2009) reported a significant decline in FMS at 9-week follow-up compared to post-intervention, but scores remained significantly higher than baseline. In the same study, FMS scores did not significantly change at post-intervention or at 9-week follow-up for the control group. These studies suggest that an instructional climate that fosters students' autonomy and emphasises self-improvement rather than competition and winning can promote lasting FMS improvements.

Previous investigations suggest that multi-component school-based interventions, which are delivered over a full academic year and underpinned by a theoretical framework, can support FMS improvements immediately following the intervention (Van Beurden et al. 2003; Lai et al. 2014; Tompsett et al. 2017; Bolger et al. 2019). However, it is difficult to decipher the most influential elements of such programmes and a lack of follow-up studies means their long-term effectiveness remains unclear (Lai et al. 2014). Due to time constraints and large curriculum demands, school-based interventions may benefit from taking a more streamlined approach. Thus, the specific elements of what makes an intervention programme effective must be identified. There is evidence to suggest that mastery-based interventions can enhance enjoyment of PE (Navarro-Patón et al. 2019) and increase primary school children's motivation to be physically active (Sproule et al. 2007). However, the effectiveness of short-duration programmes to enhance FMS proficiency levels within a typical primary school PE class is yet to be determined (Bandeira et al. 2017).

Therefore, the aim of this study was to investigate if an 8-week FMS intervention programme, delivered using a mastery-motivational climate, can significantly improve FMS proficiency levels among primary school children. A secondary aim was to examine potentially differential intervention effects according to children's sex and weight status. It was hypothesised that engaging in the intervention programme would significantly improve FMS proficiency levels for all children regardless of sex or weight status, and that these improvements would be maintained 13-months post-intervention.

Methods

A longitudinal cluster crossover design was employed to investigate the effects of an 8-week FMS intervention programme on FMS proficiency levels immediately post-intervention and at 13-months post-intervention (i.e. follow-up). The crossover design ensured that all participants in each school were provided with the opportunity to participate in the FMS programme which was critical for the recruitment process. Ethical approval was granted by the Institute's research ethics board.

Participants and setting

An a priori sample size calculation was used to determine the study size using the standard deviation of a previously conducted study with a similar study design (Draper et al. 2012). With α=0.05, power=0.8, detectable difference=1 and standard deviation=2.4, the projected sample size required minimally 186 participants in total. To account for a drop-out rate of 15%, a minimum of 214 participants had to be recruited for this study.

Participants (N=255) were conveniently recruited from Year 3 (Age: 6.9±0.4 yrs.) and Year 4 (Age: 7.9±0.4 yrs.) mainstream classes, from 4 schools in the midlands of Ireland. As the principal investigator was delivering all lessons, only four schools could be accepted into the study. Schools were informed that acceptance to the study would be granted on a first come basis, whilst others would be held as reserves should any issues arise prior to the study commencing. Preceding baseline data collection, informed consent by legal guardians and assent by eligible participants were provided. Children who failed to return signed consent forms or those with a musculoskeletal injury, disability or medical condition that limited their ability to participate in physical activity were excluded. Children with mild learning disabilities who had no difficulty following instructions were included in the study. The class teacher planned and supervised alternative activities for children who did not participate in the testing.

Procedures

At baseline, all participants in two schools were randomly assigned to the intervention-control (I-C) sequence and all participants in the remaining 2 schools to the control-intervention (C-I) sequence. Group I-C completed the intervention in phase 1 (P1) and the control condition (i.e. normal PE) in phase 2 (P2), whereas group C-I followed the reverse sequence. The intervention was implemented in place of usual PE lessons. P1 and P2 were separated by a 4-week washout (i.e. point of crossover), during which both groups were on school holidays and, therefore, not engaging in physical education or the intervention.

Figure 1 outlines the study process and the number of participants with complete TGMD-3 data at each time point. Reasons for missing data included illness, injury and family holidays. Outcome measures were assessed for all participants at five time points where time 1 (T1) was baseline/phase 1 pre-test, time 2 (T2) phase 1 post-test, time 3 (T3) post 4-week washout/phase 2 pre-test, time 4 (T4) phase 2 post-test and time 5 (T5) was at 13-months post-intervention.

****Insert Figure 1 near here****

Instruments

FMS were assessed using the valid (Temple and Foley 2017; Valentini, Zanell and Webster 2016) and reliable (Rintala, Sääkslahti and Iivonen 2017; Hulteen et al. 2020) Test of Gross Motor Development-Third Edition (TGMD-3) which includes 13 skills, namely the run, gallop, hop, skip, slide and horizontal jump in the locomotor skills category and the two-hand strike, forehand strike, kick, catch, dribble, overhand throw and underhand throw in the ball skills category (formerly object-control skills) (Ulrich 2019).

Anthropometric measurements were also recorded at each time point. Height was measured to the nearest 0.1 cm, using a portable height stadiometer (SECA 217, SECA ltd., Leicester, UK) and body mass to the nearest 0.1 kg, using a portable SECA heavy-duty scale (SECA colorata 760, SECA ltd., Leicester, UK). Body Mass Index (BMI) was derived using the equation: body mass (kg)/height (m^2). Participants were categorised as either overweight/obese or non-overweight according to the age- and gender-specific International Obesity Task Force cut-off points (Cole et al. 2000).

Intervention details

The principal investigator with over eight years' experience coaching children (mainly in athletics) and a certificate in Coaching Children from Coaching Ireland (focusing on physical literacy), delivered all intervention sessions in each school's indoor sports hall. The intervention replaced PE lessons and consisted of two 45-minute sessions per week over 8 weeks (i.e. a total of 16 sessions, 720 minutes). The class teacher arranged and supervised alternative activities for non-participating children and did not assist with the intervention in any way. Similar to the structure of a previous community-based intervention, three skills were targeted during each lesson (Bardid et al. 2017).

Although the TGMD-3 includes 13 skills, overhand and underhand throwing were grouped together, allowing for each skill to be included four times throughout the 8-week intervention. Each lesson started with a warm-up, which also included a quick discussion on the skills being targeted in the session (10 minutes), two or three separate games/activities (30 minutes) and a cool-down which also incorporated some questioning and discussion on the skills just practiced (5 minutes). Intervention sessions were delivered using the principles of the TARGET acronym (i.e. task, authority, recognition, grouping, evaluation and time) to facilitate a mastery-motivational climate (Ames 1992). An overview of the theoretical underpinning of the lesson structure which was informed by Achievement Goal Theory (Nicholls, 1984) and Self-Determination Theory (Deci and Ryan 2008) is included in the supplementary material.

During the control condition, teachers were asked to continue with their usual PE routine. Teachers typically taught one 60-minute class per week focusing on one of the six strands in

198 the Irish PE curriculum (i.e. athletics, dance, gymnastics, aquatics, outdoor and adventure, and
199 games). The exact content, duration or frequency of the control condition for each school was
200 not monitored.

201 *FMS assessment*

202 Participants were video recorded performing two trials of each skill which were retrospectively
203 scored by the principal investigator, who was not blinded to the cluster randomisation. Scores
204 for the six locomotor skills and seven ball skills were summed to determine the locomotor
205 subtest (max possible score=46) and ball skill subtest (max possible score=54) scores,
206 respectively. Both subtest scores were added to give the total FMS score (max possible
207 score=100). Two weeks before baseline data collection, the principal investigator completed
208 inter-rater reliability scoring of the TGMD-3 using the online resource on the TGMD-3 website
209 (Reliability Videos - TGMD-3, 2016). The principal investigator submitted scores for four
210 participants performing the 13 skills. The scoring was analysed by an expert who returned a
211 reliability agreement score of 99%. The principal investigator then completed intra-rater
212 reliability by assigning scores to a randomly selected subset of videos from 32 participants (i.e.
213 16 from Group I-C and 16 from Group C-I) performing each of the 13 skills two weeks after
214 baseline data collection. These videos were rescored two-weeks later. ICC values ranged from
215 good ICC=0.79 (run) to excellent ICC=0.98 (kick) (Koo and Li 2016). The detailed testing and
216 scoring procedures are described in a previous study (Kelly et al. 2019).

217 *Data analysis*

218 All data were analysed using IBM SPSS software version 25 (SPSS Inc. Chicago, IL).
219 Significance was set at $p<0.05$. All data were determined to be normally distributed.
220 Independent T-tests were used to assess the differences in age, locomotor subtest, ball skills
221 subtest and total FMS mean scores between Groups I-C and C-I at baseline. Additionally, Chi-

square analysis were run to compare the distribution of participants according to sex and weight status in each group at baseline.

The intention-to-treat principle was applied as it limits the risk of bias and provides a more accurate estimate of the effects of the intervention compared to a per protocol analysis (McCoy 2017). Linear mixed models were conducted to assess the effects of the intervention programme on FMS outcome measures (locomotor subtest score, ball skills subtest score and total FMS score) over time. Group (I-C, C-I), time (pre-phase 1[T1], post-phase 1[T2], pre-phase 2 [T3], post-phase 2 [T4], 13-months post-intervention [T5]) and group-time interaction formed the base of the model as fixed effects. Class group (Year 3/Year 4) was included as a random effect using the variance components covariance matrix. The individual participants as part of each school cluster were assessed as a repeated effect using the unstructured covariance matrix. Additionally, a group-time-sex interaction was included to investigate potential sex effects (i.e. males versus females) and a group-time-weight status interaction was included to investigate any weight status effect (i.e. non-overweight versus overweight-obese). Bonferroni adjustments for multiple comparisons were applied to limit the risk of type-1 error. Effect sizes were calculated using Cohen's d where d = 0.2, 0.5 and 0.8 represented small, medium and large effect sizes, respectively (Cohen 1988).

Finally, a binary variable was computed to define mastery/near-mastery (MNM) or poor mastery (PM) for each skill (Kelly et al. 2019; O'Brien et al. 2016; O'Brien, Belton and Issartel 2016). Mastery was assigned when a maximum score was achieved for a skill, and near mastery assigned when all but one skill criteria was correctly performed over two trials. Poor mastery was assigned when more than one skill criteria was incorrect/absent over the two trials (O'Brien et al. 2016; van Beurden et al. 2002). McNemar tests were run to identify if the proportion of participants achieving MNM for each skill significantly improved from pre to post phase 1, from pre to post phase 2 and from baseline to follow-up. Effect sizes were determined by calculating the Odds Ratio and classified as small (1.5), medium (3.5) and large (9.0) (Cohen 1988).

Results

Baseline characteristics are outlined in Table 1. Participants in Group I-C and C-I were similar at baseline for age, locomotor subtest, ball skills subtest and total FMS scores ($p>0.05$). Additionally, the distribution of participants by sex and weight status were similar across both groups ($p>0.05$).

Phase 1 (T1 to T2)

Linear mixed models revealed significant group by time interaction effects for the locomotor subtest (Figure 2), ball skills subtest (Figure 3) and total FMS scores (Figure 4). Group I-C showed a medium significant improvement from T1 to T2 for the locomotor subtest ($p<0.001$, $d=0.6$), and a large significant improvement for the ball skills and total FMS scores (both $p<0.001$, $d=1.0$). FMS scores did not change significantly for Group C-I during phase 1.

Washout (T2 to T3)

Locomotor subtest [mean difference: 1.2 (95% CI: 0.2, 2.1), $p=0.02$], ball skills subtest [mean difference: 3.8 (95% CI: 2.8, 4.8), $p<0.001$] and total FMS [mean difference: 5.0 (95% CI: 3.5, 6.5), $p<0.001$] scores significantly decreased for Group I-C during the washout phase (i.e. T2 to T3). There was no significant change in the locomotor subtest score for Group C-I during the washout phase ($p>0.05$), but their ball skills subtest [mean difference: -2.9 (95% CI: -4.0, -1.9), $p<0.001$] and total FMS scores [mean difference: -4.0 (95% CI: -5.5, -2.5), $p<0.001$] significantly increased. Locomotor subtest [**Group I-C**: mean difference: -2.2 (95% CI: -3.6, -0.7), $p<0.001$; **Group C-I**: mean difference: -1.3 (95% CI: -2.7, 0.6), $p=0.07$], ball skills subtest [**Group I-C**: mean difference: -2.6 (95% CI: -4.1, -1.1), $p<0.001$; **Group C-I**: mean difference: -2.9 (95% CI: -4.5, -1.4), $p<0.001$] and total FMS scores [**Group I-C**: mean difference: -6.7 (95% CI: -6.7, -2.2), $p<0.001$; **Group C-I**: mean difference: -4.3 (95% CI: -6.5, -2.2), $p<0.001$] were significantly higher than baseline values after the washout phase (i.e. T1 versus T3) for both groups, apart from Group C-I's locomotor subtest scores. Groups I-C and C-I had similar locomotor subtest [mean difference: 1.2 (95% CI: -0.1, 2.5), $p=0.08$], ball skills subtest [mean difference: 0.7 (95% CI: -1.0, 2.4), $p=0.4$] and total FMS scores [mean difference: 1.7 (95% CI: -0.8, 4.3), $p=0.2$] after the washout phase (i.e. at T3).

Phase 2 (T3 to T4)

A medium significant improvement for the locomotor subtest and total FMS (both $p<0.001$, $d=0.6$) scores, in addition to a small significant improvement in the ball skills subtest scores ($p<0.001$, $d=0.4$), was observed for Group C-I after the intervention (i.e. T4 versus T3). FMS scores for Group I-C did not change significantly from T3 to T4.

Follow-up

Compared to baseline scores, both groups maintained a significant improvement in their locomotor subtest, ball skills subtest and total FMS scores at follow-up. The effect size was small for both groups in the locomotor subtest scores (I-C: $p=0.02$, C-I: $p<0.001$, both $d=0.4$), whilst for the ball skills subtest and total FMS scores, Group I-C revealed medium effect sizes (both $p<0.001$, both $d=0.7$) and Group C-I large effect sizes (both $p<0.001$, $d=1.0$ and 0.9, respectively).

Sex and weight status effects

Linear mixed models revealed no significant sex-group-time interaction effects or sex-time interaction effects for the locomotor subtest, ball skills subtest or total FMS scores (all $p>0.05$). There was, however, a significant main effect for sex, for the ball skills subtest [mean difference: 4.6 (95% CI: 3.4, 5.8), $p<0.001$] and total FMS scores [mean difference: 3.8 (95%

294 CI: 1.8, 5.9), p<0.001] with males outperforming females on both aspects. There was no
295 significant difference between males and females for the locomotor subtest scores (p>0.05).

296 There were no significant weight status-group-time interaction effects for either subtest or total
297 FMS scores (p>0.05). However, overweight/obese participants had significantly lower total
298 FMS scores than non-overweight participants, which was consistent over time [mean
299 difference: 2.6 (95% CI: 0.8, 4.4), p=0.005]. Non-overweight participants had significantly
300 higher locomotor subtest scores (p<0.001); however, there was also a significant time-weight
301 status interaction effect (p=0.04). Pairwise comparison revealed that non-overweight
302 participants had significantly higher locomotor subtest scores than overweight/obese
303 participants at each time point apart from T2. Overweight and non-overweight participants did
304 not differ significantly at any time point for the ball skills subtest scores (p>0.05).

305 ****Insert Table 1 near here****

306 ****Insert Figure 2, 3 & 4 near here****

307 *Individual skill changes*

308 McNemars test indicated that mastery levels changed in the direction of poor mastery (PM) to
309 mastery/near mastery (MNM) for eight skills from pre to post-intervention (Table 2) and from
310 baseline to follow-up (Table 3). Significant improvements were reported for the gallop,
311 horizontal jump, forehand strike, overhand throw, dribble, kick, underhand throw and run for
312 Group I-C in phase 1 and for the gallop, horizontal jump, forehand strike, overhand throw,
313 dribble, hop, skip and slide for Group C-I in phase 2 (Table 2). A decrease in the proportion of
314 participants achieving MNM was observed for the horizontal jump for Group C-I in phase 1,
315 and for the overhand throw for Group I-C in phase 2 (Table 2). From baseline to follow-up,
316 mastery levels significantly changed in the direction of PM to MNM for the gallop, skip, two-

hand strike, forehand strike, kick, underhand throw, catch and dribble (Table 3). Table 2 and 3 also summarise the proportion of participants achieving MNM at each time point.

****Insert Tables 2 and 3 near here****

Discussion

This is the first study to examine if a short-duration FMS intervention programme can provide immediate and long-term improvements in Irish primary school children's FMS proficiency levels, and internationally is among the first of its kind to include older children who are attending primary school rather than pre-school. The findings support the hypothesis that an FMS intervention programme, delivered by a specialist coach over 8 weeks, can improve FMS proficiency immediately post-intervention for children with varying levels of ability. However, further studies are needed to clarify if improvements can be maintained over time.

Similar to previous research (Gallahue, Ozmun and Goodway 2012; Palmer et al. 2017; Logan et al. 2012; Morgan et al. 2013; Chan et al. 2016; Robinson and Goodway, 2009; Robinson et al. 2012), the current study results suggests that children may be more likely to master FMS if they receive developmentally appropriate specialist instruction and practice opportunities. Large and medium effect sizes were reported for the within group change in total FMS scores following engagement in the intervention in phase 1 and 2, respectively. Despite the difference in the magnitude of improvement, both groups had similar mean FMS scores after their respective intervention phases (Group I-C at T2: 64.1 versus Group C-I at T4: 63.4). The difference in effect sizes were likely due to Group C-I having a higher FMS score before starting their intervention (57.4 at T3) compared to that of Group I-C prior to their intervention (54.5 at T1). Logan et al. (2013) similarly found that lower skilled children improved more than higher skilled children following a 9-week object-control skill intervention, indicating that improvements are more difficult to obtain as skill levels improve. Although a ceiling effect is possible when assessing FMS using the TGMD (Logan et al. 2018), this was unlikely in the current study as no child achieved a maximum FMS score at any time point.

In contrast, 8 weeks of routine PE lessons did not lead to any significant change in FMS scores in either phase 1 or 2 in the current study. Although the content of the PE lessons is unknown, previous research in both Ireland (Bolger et al. 2019) and Australia (Cohen et al. 2015) similarly found no improvements in FMS proficiency levels following 8 months of usual PE. In many countries, PE is delivered by generalist teachers, most of whom have limited PE specific training (Hardman 2007). Consequently, generalist teachers tend to revert to their own experiences of PE as a child to guide their teaching (Morgan and Hansen 2008) with many of them overemphasising the games strand of the PE curriculum (Woods et al. 2018; Hardman 2007). Games based PE lessons can be beneficial if delivered in a non-competitive setting (Smith 2016); however, they are traditionally associated with competition and winning. Overemphasis on competition and winning facilitates an ego-based motivational climate (Ames 1992), which can lead to disengagement, amotivation and negative emotional experiences among lower skilled children (Garcia-Gonzales et al. 2019; Braithwaite, Spray, and Warburton 2011). Although speculative, this may be a reason why Irish primary school children struggle to develop their FMS proficiency during typical PE lessons. Further research is needed to clarify what is taught in PE and how it is taught, but perhaps teachers require upskilling on how to deliver lessons through a mastery-oriented climate (i.e. encouraging children to focus on self-improvement, rewarding individual effort and progress and avoiding social comparison and overly competitive environments) in order to facilitate FMS improvements.

Following the 4-week washout phase (at T3), FMS scores were not significantly different between both groups. Compared to T2, FMS scores at T3 significantly decreased for Group I-C. Since regular practice is essential to learning (Wulf, Shea and Lewthwaite 2010; Wulf 1991), this decrease may be due to an absence of practice opportunities. The 4-week washout coincided with Christmas school holidays, during which time participants were not engaging in any PE or FMS intervention, and non-school based sport and physical activity opportunities were likely low. Despite also being on school holidays and having not yet received the intervention, FMS scores for Group C-I significantly increased from T2 to T3 which may suggest the presence of a learning effect from repeatedly using the TGMD-3 assessment tool. FMS scores were not assessed 4 weeks after Group C-I completed the intervention. Thus, it is unknown if FMS proficiency levels decreased similar to that of Group I-C after the 4-week wash-out period. This may be worth considering in future studies to gain further insight into the potential non-linear nature of FMS development.

During assessment sessions, children observed both expert (from the demonstrator) and novice (from peers) demonstrations of each skill. Individually, each strategy can support learning (Martens, Burwitz and Zuckerman 1976; Sigmundsson et al. 2017; McMorris 2004); however, combined expert and novice observation has been shown to significantly enhance motor learning compared to observing either an expert or novice alone (Rohbanfard and Proteau 2011). Observational learning can engage similar cognitive processes that occur during physical practice (Blandin, Lhuisset and Proteau 1999). The learner can formulate an ideal movement pattern in their mind from observing an expert, whilst observing a novice performer helps the learner to detect and correct errors in the movement patterns prior to physically attempting the skill him-/herself (Adams 1986). This may explain why Group C-I improved their FMS during the wash-out period (i.e. from T2 to T3). Future intervention studies may consider using a familiarisation session for the FMS assessment procedure, particularly when assessments are conducted over a short period of time.

A limitation of many FMS intervention studies is the absence of follow-up assessments to determine their long-term effectiveness (Lai et al. 2014). Although a follow-up was included in the current study, the lack of a true control group limits the interpretation of the findings. Both groups had higher FMS scores at follow-up compared to baseline, but the improvements cannot be definitively attributed to the intervention programme. Cross-sectional studies looking at differences in FMS proficiency across age give mixed results. Behan et al. (2019) found improvements in FMS scores up to the age of 10 years among Irish primary school children, which might suggest that the follow-up scores observed in the current study may have occurred as part of normal growth and development. In contrast, plateaus in total FMS scores were reported at approximately age 7 and 8 among Belgian (Bardid et al. 2016) and Irish (Kelly et al. 2019) primary school children, respectively. The current sample were 7- to 8-years old at baseline and aged 8- to 9-years old at follow-up, thus the findings of Kelly et al. (2019) and Bardid et al. (2016) suggest that the improvements may not have occurred in the absence of specialist instruction and practice opportunities provided during the FMS intervention programme. Furthermore, studies by Robinson and Goodway (2009), Valentini and Rudisill (2004) and Robinson et al. (2017), previously noted how mastery-oriented instructional climates that aimed to improve FMS proficiency among pre-school aged children consistently facilitated immediate improvements in FMS proficiency, but evidence for sustained improvements were mixed. Whilst Valentini and Rudisill (2004) reported sustained improvements at 6-month follow-up compared to post-intervention scores, children in the other two studies had significantly lower FMS scores at 9-week follow-up compared to their post-intervention scores. The inconsistent results may be due to the varying characteristics of the participants (i.e. children in two studies were classed as developmentally delayed and were also younger than children in the current study sample), and the length of time between post-intervention and follow-up assessments (i.e. 9-weeks and 6-months post-intervention compared to 13-months in the current study).

The concept of assessing FMS learning is difficult due to the non-linear nature of skill acquisition and the multiple personal, environmental and task related factors that may impact a performance at a given moment (Newell 1986). The changes in mastery/near mastery levels for the individual skills highlights this difficulty. Despite each class group receiving the same intervention over the two 8-week intervention phases, differences were observed in relation to the specific skills that improved over time. It also provides evidence for the individual nature of motor learning (Clarke and Metcalfe, 2002) and the fact that there is no one size fits all approach to teaching FMS. The variation in FMS improvements could be interpreted as one of the strengths of adopting a mastery-oriented instructional climate, as it allows each individual to take control of his/her learning experience (Ames 1992). Perhaps the skills that improved were perceived as being more important to one group compared to another. Future studies should aim to understand the factors that contribute to variations in skill improvements by including the learners' perception of what skills they perceive to be important and why.

Previous research highlights that overweight children (Rodrigues et al., 2016; Lima et al. 2018; D'Hondt et al. 2013) and females (Coppens et al. 2019) are less likely to improve their motor competence over time compared to non-overweight children and males, respectively. FMS proficiency is a sub-component of motor competence, thus it was important to determine if those 'at risk' children benefited from participating in the current intervention programme. Similar rates of improvement were observed for participants regardless of their weight status or sex; however, consistent with previous research, we found that males remained significantly better than females in performing object-control skills (Bolger et al. 2018; Kelly et al. 2019; Behan et al. 2019) whilst non-overweight children were consistently more proficient than overweight children at locomotor skills (Kelly et al. 2019; Cliff et al. 2012).

The current results suggest that delivering interventions through a mastery-oriented climate as opposed to an ego-oriented climate may support children of all abilities to experience success and to improve their FMS proficiency at an individualistic and developmentally appropriate rate (García-González et al. 2019). Given that females continued to demonstrate poorer object-control skill proficiency than males across all five time points, future research may consider whether a gender-specific approach to FMS instruction could eliminate this divide. Additionally, a low level of perceived competence is often mentioned as a barrier to physical activity and sport participation among females (Woods et al. 2010; Mitchell, Gray and Inchley 2015) and overweight children (Morrison et al. 2018). Thus, the inclusion of measures of perceived competence would offer valuable insight into the effectiveness of future intervention programmes. Finally, it is important to mention that although the participants had better FMS proficiency at follow-up compared to baseline, the proportion of children classified as overweight or obese at follow-up increased by 7% (i.e. 28% at follow-up versus 21% at baseline). Obesity is a complex issue and can be affected by diet, genetics, activity levels, socio-cultural factors and psychological factors (Sahoo et al. 2015). Thus, although both overweight and non-overweight participants significantly improved their FMS following the intervention, when weight-maintenance or weight-loss is the goal, additional measures to those that facilitate FMS development must be considered.

The present intervention programme was delivered in an ideal situation where the instructor had specialist FMS knowledge and an understanding of mastery-motivational theory. However, many primary school teachers in Ireland have received limited training for teaching PE (Fletcher and Mandigo 2012) and, therefore, may not have the pre-requisite theoretical knowledge that was used to inform this intervention. Previous studies already indicated that teachers can be upskilled to improve the quality of their PE lessons and consequently the FMS proficiency levels of their class group (Rudisill and Johnson 2018). Aiming to determine the role of specialist instruction on FMS proficiency levels, this study acts as a steppingstone to identifying the most appropriate strategies that should be undertaken to improve the quality of

PE teaching within the primary school setting. The findings suggest that specialist knowledge is important to support FMS development. However, it is unknown if generalist teachers are willing to upskill to improve the quality of their PE lessons or if they would prefer to employ PE specialists to either solely teach PE or work alongside them as a means of improving their PE teaching ability. These factors and their feasibility should be addressed in future studies.

Study strengths and limitations

This study has some strengths and limitations. The inclusion of older children (i.e. aged 7-8 years at baseline) is novel and fills a gap in the literature as, to the authors' knowledge, previous studies with similar aims were conducted in pre-school settings (i.e. aged 3-5 years.). As all groups received the FMS intervention programme, it helped to avoid bleed-over and contamination. Additionally, the longitudinal design and inclusion of a 13-month follow-up provided a more comprehensive analysis of FMS development over time. However, limitations include the lack of a true control group at follow-up and the absence of information about what was covered in typical PE lessons, which prevents an accurate interpretation of the long-term effectiveness of the intervention. Although a large number of skills were assessed, none specifically assessed the stability division of FMS. Balance is an underlying requirement to efficiently execute many locomotor and object-control skills; however, future studies could be strengthened by assessing balance or stability skills separately. Additionally, there was a risk of bias in scoring the FMS, as the principal investigator was not blinded to participant allocation. The number of children with mild learning disabilities was not recorded and may also be seen as a limitation. Lesson fidelity was not recorded during the study; however, the principal investigator delivered all lessons to all class groups allowing for consistency throughout the study. The findings may not be generalisable to the national and international primary education settings as the intervention was delivered in ideal circumstances by an instructor with specialist FMS knowledge and an understanding of how to facilitate a mastery-motivational climate. Future research should aim to determine the fidelity and feasibility of upskilling teachers to deliver PE lessons using the concepts undertaken in the current study.

Conclusion

The results of this study suggest that a short-duration FMS intervention, focusing on specialist FMS instruction in a mastery-motivational climate, can significantly improve locomotor and ball skills at post-intervention. The long-term effectiveness is inconclusive and warrants further investigation. Typical primary school PE classes include children with a range of skill levels, interests and abilities, thus maximising engagement by all children is essential to ensure each child is provided with an equal opportunity to experience success. This may be possible when PE lessons are taught by teachers with both specialist FMS knowledge and an understanding of how to create a mastery-motivational climate as regular incentive may be needed for children to attain adequate long-term FMS improvements.

Conflict of interest

The authors declare no conflict of interest for this study.

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Figure Legends

Figure 1: Participant recruitment (n values refer to those who have full TGMD-3 data).

Note: **I-C:** Intervention-control group, **C-I:** Control-intervention group, **T1:** Pre phase 1, **T2:** Post phase 1, **T3:** Pre phase 2, **T4:** Post phase 2, **T5:** Follow-up (i.e. 13-months post-intervention).

Table 1: Baseline characteristics of study participants.

Note: Data is presented as mean ± standard deviation, [a] : Some missing data due to either a. participant decision not to do skill, b. participant joking around or c. problems with recording, **I-C:** Intervention-control group, **C-I:** Control-intervention group, **% OW-OB:** % Overweight-obese, **% Non-OW:** % Non-overweight, **%m/nm/pm:** % Mastery/near-mastery/poor mastery where mastery = correct performance of all skill criteria over two trials, near-mastery = correct performance of all but one skill criteria over two trials, and poor mastery = incorrect performance or absence of more than one criteria over two trials **H jump:** Horizontal jump, **FHS:** Forehand strike, **OHT:** Overhand throw, **UHT:** Underhand throw, **LM:** Locomotor, **BS:** Ball skill, **FMS**: Fundamental movement skill.

Figure 2: Within group and between group changes in locomotor subtest scores for phase 1, phase 2 and follow-up.

Note: **a:** Within group change for phase 1, **b:** Within group change for phase 2, **c:** Within group change from baseline to follow-up, **d:** Adjusted mean difference (**AMD**) and 95% CI; results from linear mixed model with random effect for class group, **e:** Group-time interaction from mixed model with class group as random effect, **f:** Adjusted mean difference and 95% CI between each respective I-C and C-I group (I-C minus C-I); results from linear mixed model with random effect for class group, **I-C:** Intervention-control group, **C-I:** Control-intervention group, **ES:** Effect size (Cohen's d), **T1:** Pre phase 1, **T2:** Post phase 1, **T3:** Pre phase 2, **T4:** Post phase 2, **T5:** 13-months post-intervention.

Figure 3: Within group and between group changes in ball skills subtest scores for phase 1, phase 2 and follow-up.

Note: **a:** Within group change for phase 1, **b:** Within group change for phase 2, **c:** Within group change from baseline to follow-up, **d:** Adjusted mean difference (**AMD**) and 95% CI; results from linear mixed model with random effect for class group, **e:** Group-time interaction from mixed model with class group as random effect, **f:** Adjusted mean difference and 95% CI between each respective I-C and C-I group (I-C minus C-I); results from linear mixed model with random effect for class group, **I-C:** Intervention-control group, **C-I:** Control-intervention group, **ES:** Effect size (Cohen's d), **T1:** Pre phase 1, **T2:** Post phase 1, **T3:** Pre phase 2, **T4:** Post phase 2, **T5:** 13-months post-intervention.

Figure 4: Within group and between group changes in Total FMS scores for phase 1, phase 2 and follow-up.

Note: **a:** Within group change for phase 1, **b:** Within group change for phase 2, **c:** Within group change from baseline to follow-up, **d:** Adjusted mean difference (**AMD**) and 95% CI; results from linear mixed model with random effect for class group, **e:** Group-time interaction from mixed model with class group as random effect, **f:** Adjusted mean difference and 95% CI between each respective I-C and C-I group (I-C minus C-I); results from linear mixed model with random effect for class group, **I-C:** Intervention-control group, **C-I:** Control-intervention group, **ES:** Effect size (Cohen's d), **T1:** Pre phase 1, **T2:** Post phase 1, **T3:** Pre phase 2, **T4:** Post phase 2, **T5:** 13-months post-intervention.

Table 2: Percentage change and actual percentage achieving mastery/near mastery and poor mastery in each skill for phase 1 and phase 2 for each group.

Note: **I-C:** Intervention-control group, **C-I:** Control-intervention group, **MNM**: Mastery/near mastery, **PM:** Poor mastery, **a**: Proportion of participants who change from MNM to PM, **b**: Proportion of participants who change from PM to MNM **c**: Actual % of participants who display MNM, **T1:** Pre phase 1, **T2:** Post phase 1, **T3:** Pre phase 2, **T4:** Post phase 2, † Represents percentage change from McNemar test, **OR:** Odds ratio, **H jump:** Horizontal jump, **FHS:** Forehand strike, **OHT:** Overhand throw, **UHT:** Underhand throw.

Table 3: Percentage change and actual percentage achieving mastery/near mastery and poor mastery for all participants from baseline to follow-up.

Note: **MNM**: Mastery/near mastery, **PM:** Poor mastery, **a:** Proportion of participants who change from MNM to PM from baseline to follow-up, **b**: Proportion of participants who change from PM to MNM from baseline to follow-up, **c**: Actual % of participants who display MNM at baseline/follow-up, †Represents percentage change from McNemar test, **FU:** Follow-up, **H jump:** Horizontal jump, **FHS:** Forehand strike, **OHT:** Overhand throw, **UHT:** Underhand throw.