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Sequencing effects of object control and locomotor skill during Integrated Neuromuscular Training in 6-7 year old children

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Short Title: Integrated Neuromuscular Training in Children

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Abstract

This study examined whether scheduling of object control (e.g., throwing, catching) and locomotor skills (e.g., running, jumping), within an integrated neuromuscular training (INT) program, results in different responses in motor competence, muscular fitness and perceived motor competence in 6-7 year old children. Seventy seven boys and 63 girls (n = 140) from 3 primary schools were randomised into three, 10-week interventions, Loco First (n = 50) where locomotor skills were performed first followed by object control skills; Object First (n =48) where object control skills were performed first followed by locomotor skills or a control group (n =42, CON) who undertook school Physical Education. Results indicated greater total motor competence in Loco First and Object First vs CON (P = 0.001) with the increases in motor competence being greater for Object First vs Loco First (P = 0.001). Sprint speed (10m) was lower for Object First vs CON (P = .024). Standing long jump distance was greater in Loco First vs CON (P .0001) and Object First (P = .0001). Seated medicine ball throw distance was greater for Loco First and Object First vs CON (Both P = .001). Perceived motor competence was also higher for Object First vs Loco First (P = .005) and CON (P = .001). This study suggests that scheduling object control skills before locomotor skills within school-based strength and conditioning has a greater effect on motor competence, muscular fitness and perceived motor competence in 6-7 year old children.

Keywords: Motor Development; Physical Literacy; Fundamental Movement Skills; Test of Gross Motor Development; Muscular Fitness

Introduction

Incorporating opportunities to develop motor competence alongside concomitant opportunities to develop strength and power, is becoming increasingly popular as a means to enhance children's motor competence, fitness and athletic performance (19). Low levels of motor competence have been identified as a key barrier to development of a physically active lifestyle (18). Development of motor competence has been identified as a key contributor to children's physical, cognitive and social development (18) and feature heavily in school Physical Education curricula worldwide (1,9,23). This renewed focus on motor competence in children is important as a leading antecedent of low fundamental movement skills is likely caused by early or single sport specialization, where bias is directed towards more sport-specific activity at the expense of more global motor development (19). This is coupled with an acknowledgement that children's development of muscular strength and competence in the movement patterns that underpin performance in resistance exercise offer benefits for their current and future health and athletic performance potential (19). Recent systematic review data (18, 20) has identified a need to examine effective ways in which to progress children's motor skill competency to avoid developmental delay and ensure good movement development in children and youth. This has been coupled with a need to trial and examine the efficacy of school based interventions aimed at enhancing motor competence in children (18).

Combining opportunities to develop motor competence alongside strength and power has most recently been termed 'integrated neuromuscular training (INT, 12).

INT differs from both standard strength and conditioning practice and standard physical education practice in that it integrates aspects of strength and conditioning related to strength and power development with motor competence aspects of Physical Education, in a manner that hypothetically is synergistic for physical and motor development (See 19 for a review). There however remain few published studies on the topic. One study by Faigenbaum et al (11) evaluated, what they termed an INT program, which was conducted, twice weekly, over 8 weeks, for 15 minutes prior to school Physical Education in a sample of 7-8 year old children. Significant improvements were reported in push-ups, curl-ups, single leg hop and 0.5mile run performance for INT participants compared to the control group (11). These changes led Faigenbaum et al (11) to conclude that strength and conditioning programming was a time efficient addition to school Physical Education that can positively influence children's muscular fitness and motor competence outcomes.

These assertions have more recently been supported by Duncan et al (10) who conducted a 10 week INT programme during school Physical Education in 6-7 year old children, comparing it to a control group who undertook typical Physical Education. Compared to controls, the INT group demonstrated significantly greater improvements in process (i.e., how the skills are performed) motor competence for the throw, catch, jump, run and bounce as well as significantly greater improvement in standing long jump, counter movement jump, seated medicine ball throw and 10m sprint speed. Duncan et al (10) concluded that INT may be a useful, time efficient and practical mode of exercise for children that can be incorporated into school Physical Education providing the foundation skills for later athletic development in children. The two studies by Faigenbaum et al (11) and Duncan et al (10) provide a solid foundation for the use of INT in primary schools. Despite this, there remain few studies that have examined the efficacy of INT on children's motor competence and other variables, and additional research is needed before comprehensive conclusions regarding the use of INT for children's motor and athletic development can be made.

One key aspect of interventions designed to enhance children's motor competency that has yet to be examined is whether scheduling of INT activities has an impact on the training response. Fundamental movement skills are widely conceptualised as comprising body stabilization, locomotor and object control skills (13) and there is a focus in Physical Education curricula, during early childhood, on development of locomotor (running, jumping) and object control (throwing and catching) skills specifically as precursors to development of sport specific skills (7). In relation to this topic, gender is also an important consideration as empirical studies and systematic review data suggests boys are more likely to have greater competence in FMS compared to girls (5, 18, 20). There is evidence that sequencing of activities within children's strength and conditioning programs results in different training responses (4). For example, Hammami, et al (14) reported that balance followed by power training resulted in greater improvements in dynamic balance, reactive strength and triple hop test performance, compared to power followed by balance in a sample of 12-13 year old soccer players. However, no study to date has examined whether scheduling of activity in INT influences the training response in children. The present study therefore sought to extend the evidence base relating to INT in children by examining whether scheduling of object control followed by locomotor skills within INT results in a different response in motor competence, muscular fitness and perceived motor competence to when locomotor skills are scheduled before object control skills in a sample of 6-7 year old children.

Method

Experimental Approach to the Problem

This study employed a repeated measures, cluster randomized intervention design where 6 classes from three schools in central England were allocated into three conditions: 1) INT intervention where locomotor skills were performed first followed by object control skills (Loco First); 2) INT intervention where object control skills were performed first followed by locomotor skills (Object First) and; 3) control (CON) groups. The schools involved were comparable in terms of ethnic makeup and were all within the mid-range of socio-economic status for the county in which they were based. The INT groups undertook a 10 week programme specifically designed for primary school children. INT sessions took place once per week in place of one (of the two) statutory Physical Education sessions and lasted 30-40 minutes. INT children therefore engaged in one INT and one Physical Education session per week. The CON group did not perform specific INT but attended their two statutory Physical Education classes per week. The Physical Education activities engaged in by the three groups were the same. Prior to and immediately following the intervention participants in both groups were assessed on process and product measures of motor competence, and perception of motor competence. Measurement took place at the same time of day for each group at both pre and post-test. Participants were also informed to have the same breakfast on the morning of pre and post-testing and to get adequate sleep the night before each testing day. Loco First and Object First groups undertook the same activities but in a different order where Loco First focused on locomotor skills for the first 5 weeks followed by object control skills. Object First focused on object control skills for the first 5 weeks followed by locomotor skills.

Subjects

140 Children (77 boys, 63 girls) from 3 primary schools in central England took part in this study (see Table 1) following institutional ethics approval, parental informed consent and child assent. Classes (n = 6) were randomised into either a Loco First (n = 50, 26 boys, 24 girls), Object First (n = 48, 28 boys, 20 girls) or CON (n =42, 23 boys, 19 girls) group. Following an orientation session height (cm) and mass (kg) were assessed, with children in bare feet and wearing light shorts and t-shirt, using a SECA stadiometre and weighing scales (SECA Instruments Ltd, Hamburg, Germany). All participants then undertook assessment of motor competence, muscular fitness and perception of motor competence. This process was then repeated on completion of the 10 week intervention period.

Table 1 Here

Motor competence assessment

Process measurements of motor competence were employed in the present study. Process oriented movement skill assessment are concerned with how the skill is performed (6). Four tasks (2 locomotor, 2 object control) were employed to assess FMS assessed using the Test of Gross Motor Development-2 (TGMD-2) (26). In the current study the following skills were assessed: run, jump, catch, throw. These were particularly selected as they are the key skills identified as targets for development by the UK National Curriculum for Physical Education for children of the age participating (7). Each skill comprises 3-4 components and the TGMD-2 assess whether each component of each skill was performed or not performed to determine the mastery of the skill. Each skill was video-recorded (Sony video camera, Sony, UK) and subsequently edited into single film clips of individual skills on a computer using Quintic Biomechanics analysis software v21 (Quintic Consultancy Ltd., UK). The skills were then analysed using this software and a process oriented checklist, enabling the videos to be slowed down, magnified, replayed and scored. Scores from two trials were summed to obtain a raw score for each skill. The scores for all the skills were then summed to create a total motor competence (scored 0-30) score and scores from the run and jump were summed to create a locomotor competence score (0-16) and the catch and throw, summed to create an object control score (0-14) following recommended guidelines of administration of the TGMD-2 (26). Two researchers experienced in the assessment of children's movement skills (having previously assessed movement skills in the context of a previous research study) analysed the motor competence videos. Both raters had been previously trained in two separate two-three hour sessions by watching videoed skills of children's skill performances and rating these against a previously rated 'gold standard' rating. Congruent with prior research (2), training was considered complete when each observer's scores for the two trials differed by no more than one unit from the instructor score for each skill (>80% agreement). Inter- and intra-rater reliability analysis was performed for all the motor skills between the two researchers. Inter-rater reliability was 92.3% and intra-rater reliability was 97.6%, demonstrating good reliability (16).

Measures of muscular fitness

Three measures of muscular fitness; 10m flying sprint time, standing long jump and seated medicine ball (1kg) throw were assessed, procedures were congruent with those used previously by Duncan et al (10) in their evaluation of school based INT. A 10-metre sprint run was timed using smart speed gates (Fusion Sport, Coopers Plains, Australia). Two infra-red gates were set up 10 metres apart. The participant had a flying start to ensure that sprint speed (Secs) was measured independently of the acceleration phase. Standing long jump (cm) was measured using a tape measure and following procedures described by Peterson (21). The seated medicine ball throw, using a 1kg medicine ball, has been identified as a reliable and valid measure of upper body strength in children as young as 5 years old (8). The medicine ball throw was conducted as a measure of upper body strength following procedures reported by Davis et al (8). Children sat on the floor before throwing the medicine ball forwards like a chest pass three times with furthest distance thrown (cm) assessed using a tape measure. Children were instructed to throw the medicine ball with both arms and where a throw was executed with use of only one arm, the trial was repeated. In a subsample of participants (n = 20), one week test retest reliability was determined. Intraclass correlation coefficients for the three measures of muscular fitness were .9, .94, and .81, for the flying 10m sprint, standing long jump and seated medicine ball throw respectively.

Perception of Motor Competence

Recognising that perception of physical and motor competence is also an important psychosocial variable which is related to actual motor competence and physical activity (24), perceived motor competence was also assessed in the present study. The Pictorial Scale of Perceived Movement Skill Competence (PMSC) for young children (3) was used to assess children's perceived movement skill competence in the same four skills as the TGMD-2 process measures. The PMSC was assessed on a separate occasion, and prior to, assessment of process and product motor competence. The PMSC has been described extensively elsewhere (3) and shows good validity and reliability. For each skill, children were shown two illustrations (sex-specific) of a child performing the skill competently and less competently. Each child was asked, "This child is pretty good at throwing, this child is not that good at throwing: which child is most like you?" From the selected picture, children were asked to further indicate their perceived competence as more or less identifying with the depiction/options for the competent picture included 4: Really good at… or 3: Pretty good at…, and for the not so competent picture included 2: Sort of good at… or 1: Not that good at…. Possible scores for the entire scale ranged from 4-16 with higher scores being indicative of higher perceived competence. Two week test-retest reliability data, available in a subsample of children (n = 43, 22 boys, 21 girls, mean age = 5.6 ± .48 years), indicated good agreement (Intraclass correlation coefficient = .86, CI = .74 - .92).

INT Program

The programs used in the present study were specifically designed for primary school children. The programs were based on earlier reports on resistance training, neuromuscular conditioning and motor development for children of the ages involved in the study (7,11, 25) and recent work on school based INT (10). Both Loco First and Object First groups undertook one session of INT, lasting 30-40mins per week, for 10 weeks, in place of one of their normal school Physical Education lessons.

This decision was taken, congruent with studies examining efficacy of school based movement interventions (5, 10, 20), in order to have little disturbance on the school curriculum, to be time efficient, to create a design that could be realistically integrated into the school curriculum. The INT programs were also inexpensive and developmentally appropriate. The INT groups also undertook a second weekly Physical Education lesson during the intervention period, as part of statutory Physical Education, which was focused on team games (Hockey and Basketball). The CON group continued their twice weekly statutory Physical Education lessons (Hockey and Basketball) and there was no difference in the delivery and content of the statutory Physical Education lessons for INT and CON groups.

The principal investigator delivered all the intervention sessions with the assistance of a primary school teacher. The other Physical Education session for the INT group and Physical Education sessions for the CON group were delivered by the Physical Education teacher and in accordance with guidelines for the National Curriculum for Physical Education in England. The principal investigator documented adherence to the programme and compliance with the INT program. Any child who missed more than 2 sessions in the 10 week intervention period was not included in final analysis. This resulted in 4 exclusions from the final data set for analysis, 2 from the CON group due to sickness and 2 from the Object First group (1 due to sickness, 1 due to other absence).

The activities undertaken by the Loco First and Object First groups were identical but the scheduling of the activities differed. Both INT programs consisted of the same mobility focused warm up exercises (deep squat, bear crawls). This was followed by a series of fundamental movement exercises focused on the development of motor competence. These were based on developmentally appropriate activities (25) to enhance locomotor and object control skills in children aged 5-8 years old. The Loco First group undertook 5 weeks of locomotor based activity, followed by 5 weeks object control activity whereas the Object First undertook the same activities with the scheduling of locomotor and object control skills reversed.

Table 2 outlines the structure and content of the two INT programs. Similar to other research using this approach with children (10, 11), participants in the intervention groups also received skill-specific feedback on the quality of each movement and were taught the value of initiating exercises from an athletic stance (e.g., eyes level, chest over knees, back slightly arched, knees slightly bent and feet wider than shoulders).

Table 2 Here

Statistical Analyses

Recognizing there were significant differences between groups in baseline scores for Total motor competence (P = .045), Locomotor motor competence (P = .002), medicine ball throw distance, 10m sprint speed and PMSC scores (all P = .001), the post intervention scores were used as dependant variables in the current study controlling for baseline scores. Mean ± SD for the variables that were significantly different at baseline for each group are presented in Table 3. In order to examine any differences in motor competence (total, locomotor and object control motor competence), muscular fitness (standing long jump, medicine ball throw distance and 10m sprint speed) and perception of motor competence (PMSC scores), a series of univariate analysis of covariance (ANCOVA) were used with post intervention scores for each variable as the dependent variable and baseline values for each variable as the covariate. Gender and Group (Loco First, Object First, CON) were used as between subjects factors. Partial η^2 was used as a measure of effect size. Where any significant differences were found post hoc pairwise comparisons (Bonferroni adjusted) were employed to examine where the differences lay and Cohen's *d* was also used to determine effect size between groups. A priori power analysis indicated that, in order to detect any interaction effects, with a medium effect size, P value of 0.05 and at 80% power, a sample size of 42 participants per group was required. Given the limitations of data presentation using bar graphs (27), data were visually presented following procedures advocated by Weissgerber et al (27) by presenting means and data distribution in figures to ensure more complete presentation of data. The Statistical Package for Social Sciences (SPSS, Version 22, IBM Corp, Armonk, New York) was used for all analysis.

***Table 3 Here**

Results

Measures of motor competence

For total motor competence scores, results indicated that baseline total motor competence score was significant as a covariate (F 1,133 = 192.1, P = 0.001, Pη^2 = .591, β .727). Higher baseline total motor competence was associated with a higher total motor competence post intervention. There was no significant gender X group interaction (P>0.05). Significant main effects were evident for gender (F 1,133 = 4.921, P = 0.028, Pη^2 = .036) and group (F 2,133 = 69.6, P = 0.001, Pη^2 = .511). Bonferroni post hoc pair wise comparisons indicated that total motor competence was significantly greater (P = 0.028, *d* = 0.2) for boys (16.6 ± .26) compared to girls (15.7 ±.28). For group, there were significant differences in total motor competence between Loco First and Object First (Mean diff = -2.5, P =0.001, *d* = 0.5), Loco First and CON (Mean Diff = 3.09, P = 0.001, *d* = 0.67) and Object First and CON (Mean diff = 5.6, P = 0.001. *d* = 1.0). Mean and data distribution of total motor competence according to group are presented in Figure 1.

Figure 1 Here

When data were then reanalysed using Locomotor motor competence scores, results were similar to when total motor competence was examined. Baseline locomotor motor competence score was significant as a covariate (F 1,133 = 148.7, P = 0.001, Pη^2 = .528, β -.278), where higher baseline locomotor motor competence was associated with higher locomotor motor competence post intervention. There was no significant gender X group interaction (P>0.05). There were significant main effects for gender (F 1,133 = 4.4, P = 0.04, Pη^2 = .032) and group (F 2,133 = 36.2, P = 0.001, Pη^2 = .353). Bonferroni post hoc pair wise comparisons indicated that locomotor motor competence was significantly greater ($P = 0.05$, $d = 0.2$) for boys (9.6 ± .2) compared to girls (8.9 ±.21). For group, there were significant differences in locomotor motor competence between Loco First and CON (Mean diff = 2.255, P =0.001, $d = 0.7$) and Object First and CON (Mean Diff = 2.981, P = 0.001, $d = 0.9$). There was no significant difference between Loco First and Object First (Mean diff 0.72, P = 0.136, $d = 0.2$). Mean and data distribution of locomotor motor competence according to group are presented in Figure 2.

Figure 2 here

For object control motor competence, baseline object control motor competence score was significant as a covariate ($F_{1,133} = 104.5$, $P = 0.001$, $P\eta^2 = .440$, β -.612), where higher baseline object control motor competence was associated with higher object control motor competence post intervention. There was no significant gender X group interaction ($P>0.05$) and no significant gender main effect ($P = 0.06$). There was a significant main effect group ($F_{2,133} = 95.1$, $P = 0.001$, $P\eta^2 = .589$, See Figure 3). Bonferroni post hoc analysis indicated that object control motor competence was significantly greater in Loco First compared to CON (Mean diff = .874, P= .005, d = 0.3) and Object First compared to CON (Mean diff = 3.576, P = 0.0001, $d = 1.4$). Object control motor competence was also significantly greater in Object First compared to Loco First (Mean diff = 2.702, P = 0.0001, $d = 1.0$).

Figure 3 here

Measures of Muscular Fitness

For 10m sprint speed, baseline 10m sprint time score was significant as a covariate ($F_{1,133}$ = 176.2, P = 0.0001, $P\eta^2$ = .570, β .520), indicating that faster baseline 10m sprint scores were associated with faster 10m sprint speed post intervention. There was no significant gender X group interaction and no significant gender main effect (both P>0.05). There was a significant main effect for group ($F_{2,133}$ = 3.92, P = 0.02, $P\eta^2$ = .056, See Figure 4). Bonferroni post hoc analysis indicated that 10m run speed was significantly quicker for Object First compared to CON (Mean diff = .112, P = .026, *d* = 0.4). There were no significant differences between Object First and Loco First (Mean diff = .021, P = .999, *d* = 0.007) and Loco First and CON (Mean diff = .091, P = .083, *d* = 0.03).

***Figure 4 Here**

For standing long jump, as with sprint speed, baseline standing long jump distance was also significant as a covariate ($F_{1,133}$ = 159.5, P = 0.0001, $P\eta^2$ = .547, β .709), where smaller baseline standing long jump distance was associated with smaller standing long jump distance post intervention. There was no significant gender X group interaction (P>0.05). Results did indicate significant main effects for gender ($F_{1,133}$ = 8.94, P = 0.003, $P\eta^2$ = .063) and group ($F_{2,133}$ = 12.6, P = 0.001, $P\eta^2$ = .161). Bonferroni post hoc pair wise comparisons indicated that change in standing long jump was significantly greater (P = 0.03, *d* = 0.3) for boys (121.5 ± 1.3) compared to girls (115.5 ± 1.4). The change in standing long jump was also significantly greater in Loco First compared to CON (Mean diff = 10.675, P = .0001, *d* = 1.1) and Object First (Mean diff = 9.666, P = 0.001, *d* = 0.5). There was no significant difference between Object First and CON groups (Mean diff = 1.14, P = 1.0, *d* = 0.06). Mean and data distribution of standing long jump distance according to group are presented in Figure 5.

Figure 5 here

In regard to seated medicine ball throw performance, as with analysis of other variables, medicine ball throw distance as a covariate was significantly associated with change in medicine ball throw distance (F 1,133 = 207.4, P = 0.0001, Pη^2 = .611, β .748). Higher baseline scores were associated with a higher scores post intervention. There was no significant gender X group interaction and no significant main effect for gender and (both P >0.05). There was however, a significant main effect for group (F 2,133 = 22.5, P = 0.001, Pη^2 = .255). Both Loco First (Mean diff = 28.871, P = 0.001, *d* = 0.6) and Object First (Mean diff = 28.148, P = 0.001, *d* = 0.6) had significantly greater seated medicine ball throw distance compared to CON (See Figure 6). There was no significant difference between Loco First and Object First groups (Mean diff = 0.723, P = 1.0, *d* = 0.01).

Figure 6 Here

Perception of Motor Competence

When results for perceived motor competence scores were considered, baseline perception of motor competence scores were significant as a covariate (F 1,133 = 253.9, P = 0.0001, $P\eta^2$ = .665, β .674), where higher baseline scores were associated with higher scores post assessment. There was no significant gender x group interaction nor a significant main effect for gender (both P>0.05). There was however a significant main effect due to group (F 2,133 = 9.413, P = 0.001, $P\eta^2$ = .128, See Figure 7). Bonferroni post hoc analysis indicated that perception of motor competence was greater in the Object First group compared to Loco First (Mean diff = 1.04, P = .005, *d* = 0.36) and CON groups (Mean diff = 1.394, P = .001, *d* = 0.5). There was no significant difference between Loco First and CON groups (Mean diff = 0.354, P = .717, *d* = 0.1).

Figure 7 Here

Discussion

The results of this study demonstrate that replacing one school physical education lesson per week, for 10 weeks, with INT produces positive changes in motor competence, perceived motor competence and measures of muscular fitness, compared to a control group who undertook statutory school physical education only. This finding supports the efficacy of INT with children and extends the work of prior research evidencing that INT (10, 11) and motor competence specific interventions (5,

20) are effective. The results of the current study also support prior work evidencing that motor competence can be enhanced via Physical Education based interventions that focus on throwing, catching and locomotor activity (20).

The key novel finding in the present study is that the sequencing of activities within the INT program resulted in different effects. When children engaged in INT focused on object control skills first followed by locomotor skills, the improvement in total motor competence scores was superior to that seen when children engaged in INT focused on locomotor skills first followed by object control skills. No study to date has examined this issue in the context of INT or motor competence. The current results do however align with research on youth athletes in the context of sequencing balance and power training (4, 14). Boys also had significantly better total and locomotor motor competence scores than girls. The current study does not present novel data in relation to gender differences in motor competence and such a finding is congruent with the literature suggesting that boys score more highly for motor competence compared to girls (5, 18, 20).

The greater change in total motor competence seen in the Object First group can be explained by examining the changes in locomotor and object control motor competence separately. Both Loco First and Object First groups improved in locomotor motor competence to the same extent. However, increases in object control motor competence were superior for the Object First group compared to the INT Loco group. This would appear to suggest that scheduling object control skills first followed by locomotor skills enables more effective development of object control skills than scheduling locomotor skills before object control skills. The two intervention programmes employed in the present study were identical other than the order in which they were administered. When measures of muscular fitness are considered, both Loco First and Object First resulted in similar improvements in seated medicine ball throw distance and 10m sprint speed and Loco First resulted in a greater change in standing long jump distance compared to Object First. Such changes are in broad agreement with prior INT studies conducted by Faigenbaum et al (11) and Duncan et al (10). The changes seen in relation to sprint speed are also congruent with other school-based studies that evidenced enhanced 10m sprint speed as a consequence of motor competence interventions (5) and INT interventions (10) conducted within Physical Education lessons.

Unpicking the findings of the current study is difficult as no research to date has examined whether scheduling of motor competence activity results in a different response to intervention. Bird and Stuart (3), in their work suggested that performing balance training before power training with youth athletes is preferable as initial development of sensorimotor skill can subsequently enhance power training. Likewise, Hammami et al (14) reported that 4 weeks balance training followed by 4 weeks plyometric training resulted in enhancements in reactive strength index, absolute and relative leg stiffness and triple hop test performance, compared to when plyometric was undertaken before the balance training. Hammami et al (14) suggested that balance training first creates a preconditioning effect that augments the changes seen in power training. The focus of the present study is somewhat different to balance and power training but object control skills are recognised to be more difficult to improve than locomotor skills (20). This is because object control skills have greater skill component complexity and perceptual demand than locomotor skills, requiring more intensive skill instruction and practice (20). Meta-analytical research has also reported large effect sizes for motor competence interventions on locomotor skills but only medium effect sizes for object control skills (20), supporting the above statement.

It may be that focusing more on object control skills initially allows for greater total time across an intervention programme with which to develop those skills.

No injuries occurred throughout the training period and observations suggest that INT was well-received by the participants. Collectively, this demonstrates the potential value of incorporating a time-efficient, inexpensive, developmentally appropriate INT program in primary school Physical Education. Irrespective of scheduling, INT enhances motor competence and muscular fitness compared to statutory Physical Education. The use of such an approach in 6-7 year old children may therefore provide a stronger athletic foundation for children to build upon using more advanced strength and conditioning type interventions later in childhood.

The importance of perceived motor competence in the association between actual motor competence and physical activity, weight status and fitness has been acknowledged as part of the Stodden et al (22) conceptual model of motor competence development in children. The effect of movement based interventions on psychosocial variables such as physical self-efficacy has also been demonstrated in motor competence (5) and INT (10) interventions. A child's perception of their own competence is a key aspect of child well-being and central to willingness to engage in different physical activities and sport related tasks (15). The results of the current study suggest that engaging in object control activity first resulted in significantly greater changes in perceived motor competence scores compared to CON and Object First groups. Importantly, the PMSC used to assess perceived competence in the currently study is directly aligned with the assessment of motor competence. This enables the changes in actual and perceived motor competence to be considered together, and also addresses a key criticism of prior literature on the topic (17). Like, actual motor competence, scheduling object control activities first within an INT programme appears to result in a greater change in perceived competence than when locomotor activities are scheduled first or when on Statutory Physical Education was undertaken. Despite the paucity of studies examining the effects of resistance exercise on psychosocial variables in children (22), the results of the present study do support meta-analytical data (22) and INT research (10) suggesting resistance exercise type interventions can enhance psychosocial variables in children to a greater extent than control groups.

This aspect of the current study raises another key aspect for coaches wanting to employ INT with children. As children grow and develop they are more likely to be proficient in any given motor skill and process oriented assessments particularly may not be able to differentiate children who excel at a specific motor skill, compared to those who are proficient (20). The results of this study should therefore indicate that INT is not a replacement for Physical Education in primary schools. Rather INT should be seen as complimentary to statutory Physical Education and an activity which explicitly fits the remit of primary school Physical Education Curricula in many countries which provides a short term stimulus to accelerate motor competence in younger children (1, 9, 23). It is also important to highlight that INT is not simply strength and conditioning programming for children. The focus of INT should be on integrating exercises or activities that focus on both motor skill development and also strength and power. While this approach sits under the umbrella of strength and conditioning programming, it requires careful focus on intertwining opportunities to develop physical performance with skill performance. Early inclusion of a 10 week block of INT where object control skills are the initial focus within Physical Education might provide a stronger foundation for subsequent development of sports specific skills through school Physical Education. This suggestion is however speculative and requires further study.

There are some limitations to the current study. The findings reported here are limited to children within Key Stage 1 of the British curriculum. Key Stage 1 of the British curriculum spans the age range 5-7 years and for the Physical Education subject area, has a particular aim to master basic movements including running, jumping, throwing and catching and begin to apply them in a range of activities. Given the aforementioned (20) issues where older children are more likely to be more competent and the different developmental trajectories of children through the primary school age range, caution is needed if considering applying the INT program trialled here to children older than 7 years of age. Motivation to take part in both pre and post intervention testing and the interventions themselves are also an important consideration. The participants in the current study all appeared to be engaged and interested in the intervention activities. Motivation for exercise was not however assessed. This would be an interesting and useful addition to future studies examining the effects of school based strength and conditioning programs on children's motor competence.

This is the first study to examine whether scheduling of object control and locomotor activities within INT results in a differential effect on children's motor competence, muscular fitness and perceived motor competence. However, we are conscious that the pre to post design here does not allow examination if there were any longer term benefits to the program. Given the suggestion that object control skills take a longer time to master than locomotor skills, it would have been useful to examine if object control skills developed further post intervention, particularly for the Loco First group, who received this element in the latter half of their INT intervention.

Understanding if there are longer term benefits to participating in such a program was beyond the remit of the current study and future research examining longer would be welcome in investigating this issue. INT is also conceptualised as an integrative intervention model which includes multiple components (e.g., strength, balance, power, skill development) (12). Like prior research on the topic (10, 11), It is therefore difficult to assess the contribution of each component in achieving the overall outcomes reported here. Irrespective, the interventions trialled within this study did include the 6 essential components recently recommended for inclusion in INT programmes for pediatric populations (12).

Practical Applications

The results of this study suggest that replacing 1 of the 2 weekly statutory Physical Education lessons with an integrated neuromuscular training program over a 10 week period results in positive improvements in fundamental movement skill, muscular fitness and perceived motor competence in children 6-7 years of age. Such changes are not seen to the same magnitude in children who undertook 2 lessons of statutory Physical Education over the 10 week period. The changes in fundamental movement skill, muscular fitness and perceived motor competence are also greater for children who undertook INT with a focus on object control skills followed by locomotor skills, compared to INT with a focus on locomotor skills followed by object control skills. Integrated neuromuscular training, particularly with an initial focus on object control skills, may therefore be a useful, time efficient and practical mode of exercise for children which can be used to build the fundamental movements on which more advanced sports skills and longer term physical activity are based. Including strength and conditioning practices within statutory Physical Education appears to offer positive opportunity for instilling good movement patterns in children and enhancing perception of competence for short and potentially longer term benefit relating to both health and academic potential.

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Figure Legends

Figure 1. Scatterplot showing the Mean (filled bar) and data distribution (circles) of Total motor competence (0-30) in INT Loco, INT Obj and CON groups post intervention.

Figure 2. Scatterplot showing the Mean (filled bar) and data distribution (circles) of Locomotor motor competence (0-16) in INT Loco, INT Obj and CON groups post intervention.

Figure 3. Scatterplot showing the Mean (filled bar) and data distribution (circles) of Object Control motor competence (0-14) in INT Loco, INT Obj and CON groups post intervention.

Figure 4. Scatterplot showing the Mean (filled bar) and data distribution (circles) of 10m sprint speed (secs) in INT Loco, INT Obj and CON groups post intervention.

Figure 5. Scatterplot showing the Mean (filled bar) and data distribution (circles) of standing long jump (cm) in INT Loco, INT Obj and CON groups post intervention.

Figure 6. Scatterplot showing the Mean (filled bar) and data distribution (circles) of seated medicine ball throw (cm) in INT Loco, INT Obj and CON groups post intervention.

Figure 7. Scatterplot showing the Mean (filled bar) and data distribution (circles) of perceived motor competence scores (0=16) in INT Loco, INT Obj and CON groups post intervention.

	Loco First (n = 50)		Object First (n = 48)		CON (n = 42)	
	Mean	SD	Mean	SD	Mean	SD
Age (years)	6.4	0.5	6.0	0.7	6.2	0.5
Height (m)	1.20	0.05	1.18	0.06	1.15	0.07
Body Mass (kg)	23.5	3.4	22.7	3.6	22.5	4.4

Table 1. Descriptive statistics (Mean ± SD) of age, height and body mass for Loco First, Object First and CON groups

	Loco First (n = 50)		Object First (n = 48)		CON (n = 42)	
	Mean	SD	Mean	SD	Mean	SD
Total Motor Competence (0-30)	10.8	3.8	12.6	3.6	11.0	3.9
Locomotor Motor Competence (0-16)	5.8	2.6	7.6	2.6	6.2	2.4
Medicine Ball Throw Distance (cm)	171	5.3	143	5.5	133	5.8
10m Sprint Speed (Secs)	3.2	0.51	3.2	0.40	2.9	0.32
Perceived Motor Competence (4-16)	10.6	3.3	13.9	1.8	11.8	3.4

Table 3. Mean ± SD of variables that differed at baseline Loco First, Object First and CON groups

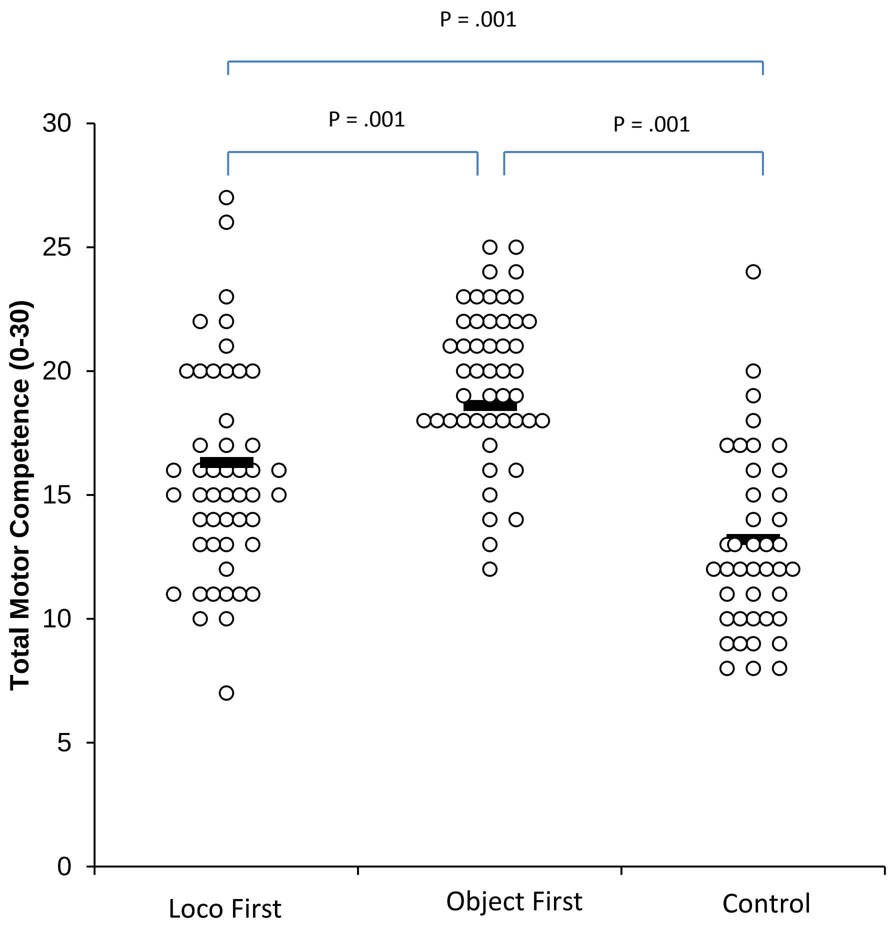
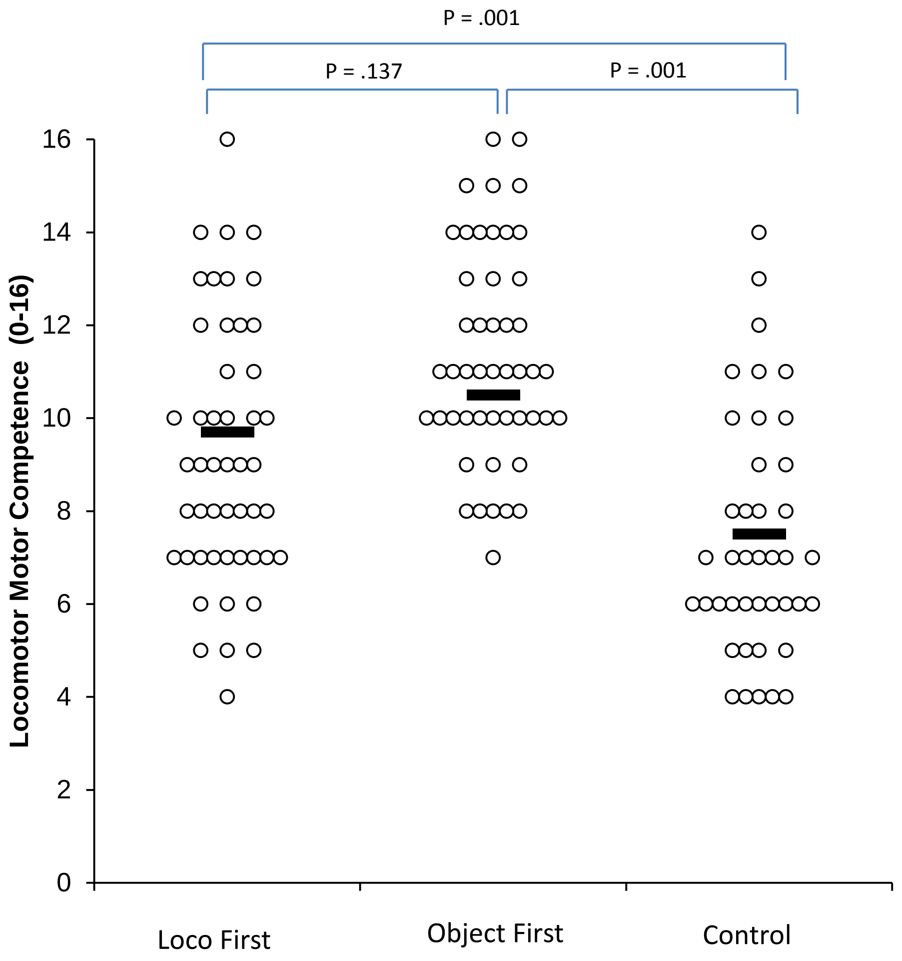

P = .001
P = .001
P = .001
Total Motor Competence (0-30)
30
25
20
15
10
5
0
Loco First
Object First
Control

Figure 1.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P = .137
P = .001
Locomotor Motor Competence (0-16)
16
14
12
10
8
6
4
2
0
Loco First
Object First
Control

Figure 2.

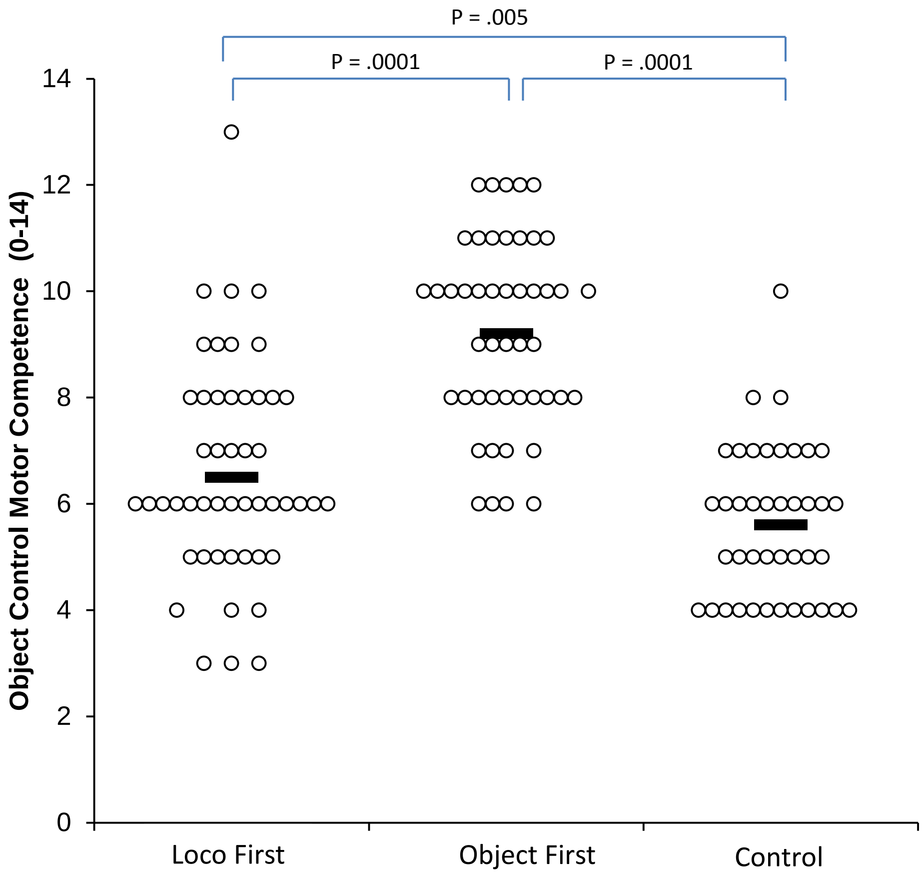
P = .005
P = .0001
P = .0001
Object Control Motor Competence (0-14)
14
12
10
8
6
4
2
0
Loco First
Object First
Control

Figure 3.

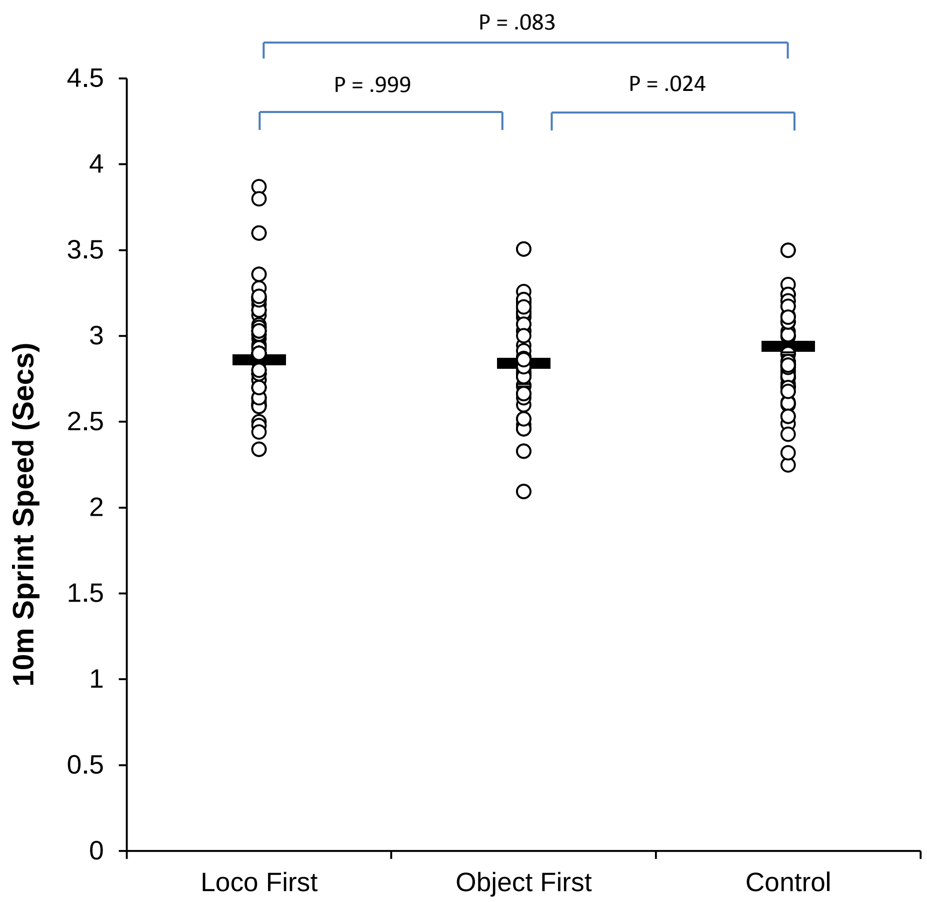
P = .083
P = .999
P = .024
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
10m Sprint Speed (Secs)
Loco First
Object First
Control

Figure 4.

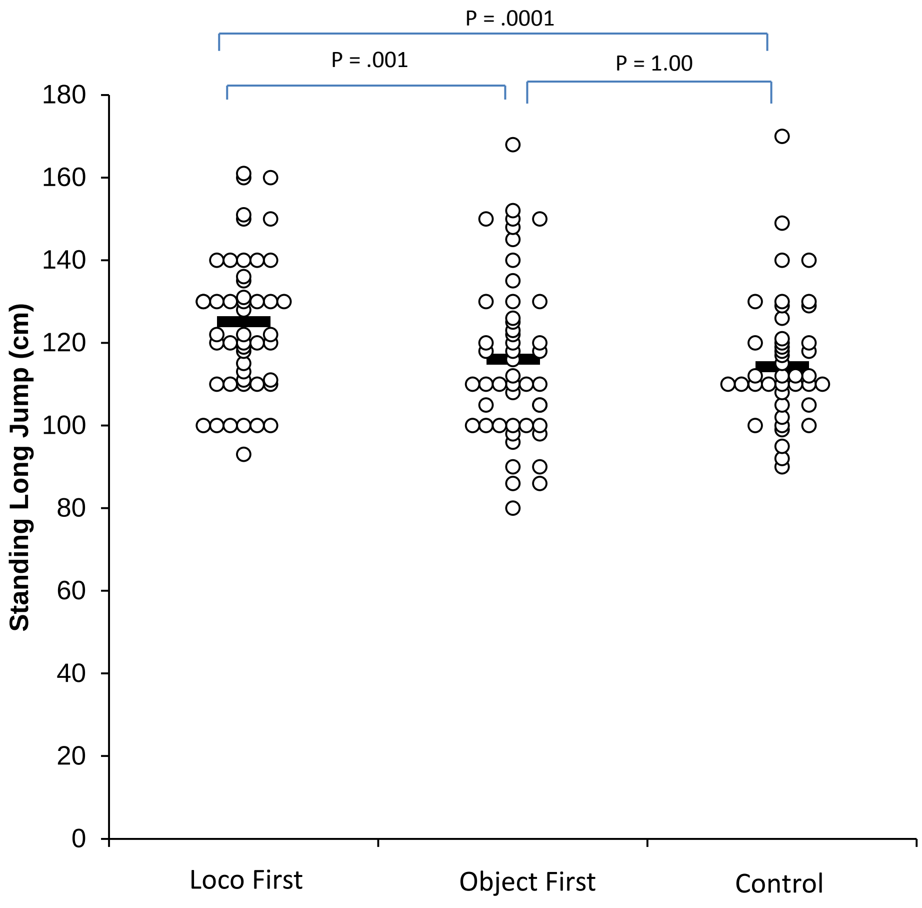
P = .0001
P = .001
P = 1.00
Standing Long Jump (cm)
180
160
140
120
100
80
60
40
20
0
Loco First
Object First
Control

Figure 5.

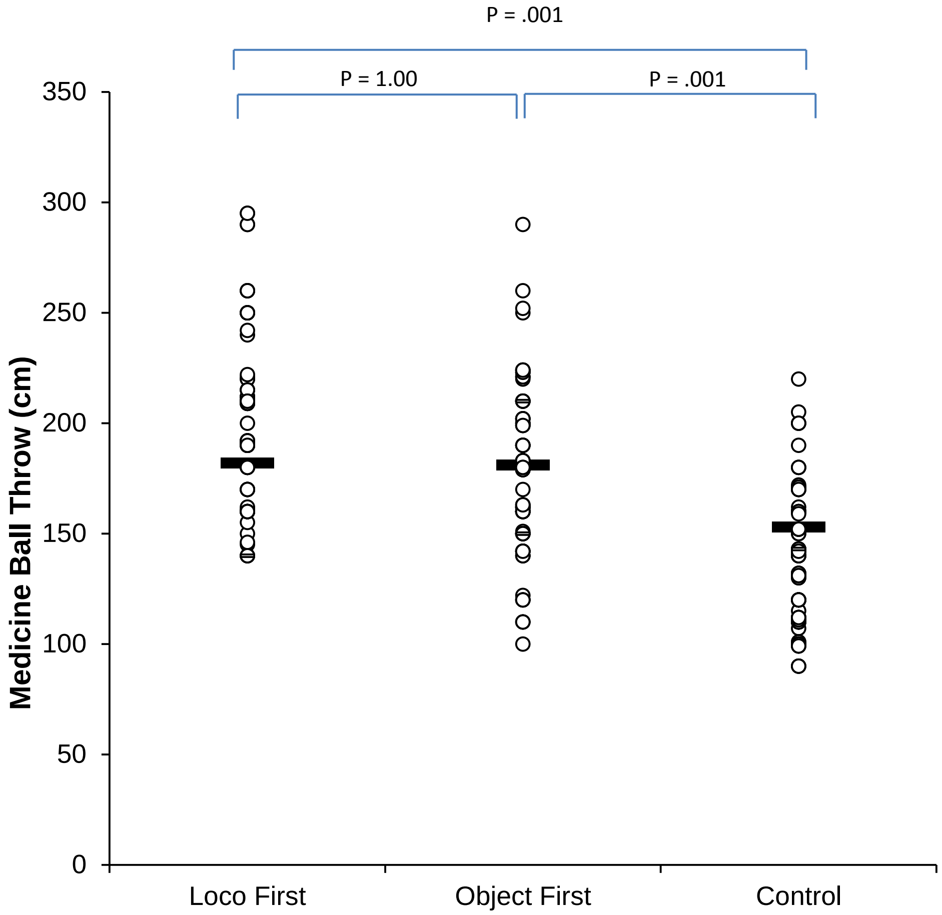
P = .001
P = 1.00
P = .001
Medicine Ball Throw (cm)
350
300
250
200
150
100
50
0
Loco First
Object First
Control

Figure 6.

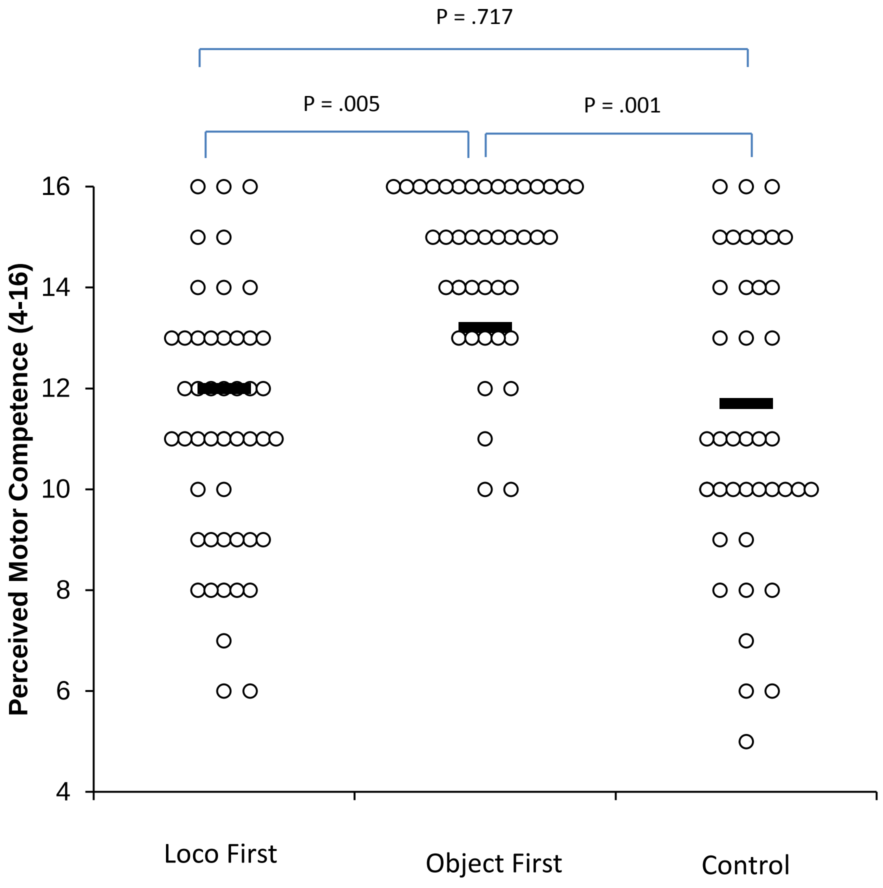
P = .717
P = .005
P = .001
Perceived Motor Competence (4-16)
16
14
12
10
8
6
4
Loco First
Object First
Control

Figure 7.