The effects of 10 weeks Integrated Neuromuscular Training on fundamental movement skills and physical self-efficacy in 6-7 year old children

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The effects of 10 weeks Integrated Neuromuscular Training on fundamental movement skills and physical self-efficacy in 6-7 year old children

Short Title: Integrated Neuromuscular Training in Children

Abstract

Integrated neuromuscular training (INT) has been suggested as an effective means to enhance athletic potential in children. However, few studies have reported the effects of school based INT programs. This study examined the effect of INT on process and product fundamental movement skill measures and physical self-efficacy in 6-7 year old children. Ninety-four children from 2 primary schools were randomised into either a 10 week INT program or a control group CON (n =41) group. Results indicated significantly greater increases in process FMS scores in INT vs CON (P = 0.001). For product measures of FMS, 10m sprint time, counter movement jump, seated medicine ball throw and standing long jump (all P = 0.001), all significantly increased to a greater extent in the INT group vs CON. A significant group (INT vs CON) X time (pre vs post) X gender interaction for physical self-efficacy revealed increased physical self-efficacy pre to post INT, compared to CON but only for boys (P = 0.001). For girls, physical self-efficacy was not significantly different pre to post the 10 week period for INT and CON groups. The results of this study suggest that replacing 1 of the 2 weekly statutory PE lessons with an integrated neuromuscular training programme over a 10 week period results in positive improvements in fundamental movement skill quality and outcomes in 6-7 year old children. INT also appears to increase physical self-esteem to a greater extent than statutory PE but only in boys.

Keywords: Motor Development; Physical Literacy; Skill; Test of Gross Motor Development

Introduction

Increasing sedentary behaviour and decreasing engagement in sufficient levels of moderate to vigorous physical activity in children is considered a current public health concern (12). Low levels of fundamental movement skill (FMS) competency have been identified as a key barrier to development of a physically active lifestyle (15) and, of current concern, a growing number of children are now presenting with developmental delays in FMS competence (16). The mastery of fundamental movement skills (FMS) has been identified as a key contributor to children's physical, cognitive and social development as well as providing the foundation for an active lifestyle and healthy weight throughout life (15). Development of motor competence is also a key pillar of school Physical Education (PE) curricula worldwide (1,7,21), yet a leading antecedent of low FMS proficiency is likely caused by early or single sport specialization, where bias is directed towards more sport-specific activity at the expense of more global fundamental movement skill development (17). There is thus a need to examine effective ways in which to progress children's motor skill competency with systematic review data (15, 18) suggesting a need to trial and examine the efficacy of school based interventions aimed at enhancing motor competence in children.

Recently, integrated neuromuscular training (INT) programmes have shown promise as a means to enhance both children's FMS and fitness (9). INT programmes incorporate a variety of essential motor skills (Locomotion, stabilisation and manipulation) alongside concomitant opportunities to develop strength and power (10). They are considered an essential strategy from which children can enrich their motor learning experience and maximise FMS development as they involve a combination of efficient cognitive processing, correct fundamental movement patterns and muscular force production (17, 18). Despite the promise that INT may offer in terms of children's development, there are few published studies on the topic. Faigenbaum et al (9) conducted one such program, running a twice weekly INT intervention before school PE, lasting 15 minutes per session, over 8 weeks with 7-8 year old children. In their study, Faigenbaum et al (9) reported significant improvements in push-ups, curl-ups, single leg hop and 0.5mile run performance for INT participants compared to the control group. Faigenbaum et al (9) concluded that INT is a time-efficient addition to school PE that can positively influence health and skill related fitness and might be an important 'first-step' in enhancing children's FMS.

While the aforementioned work is a worthy addition to the literature in this area multiple questions remain as to the utility and efficacy of INT programmes as a means to enhance children's FMS. No study to date has examined whether INT programs actually influence FMS as well as the fitness components that underpin FMS. The work by Faigenbaum did not assess FMS or any component of object manipulation within their study. Nor did they examine any psychosocial factors that may act downstream of physiological changes resulting from any conditioning programme. The Stodden (22) model of FMS development suggests perceived motor competence may be equally important as actual competence in enabling children to become physically active. Likewise, physical self-efficacy is also a key psycho-social variable related to children's future physical activity and one which school based interventions have positively influenced (2).

The present study therefore sought to address several gaps in the literature relating to INT in children. The aim of the current study was to determine the effect of 10 weeks INT on process and product fundamental movement skill measures and physical self-efficacy in British Primary school children.

Method

Experimental Approach to the Problem

This study employed a repeated measures, cluster randomized intervention design where 4 classes from two schools in central England were cluster randomised into integrated neuromuscular training intervention (INT) or control (CON) groups. The schools involved were comparable in terms of ethnic makeup and were both within the mid-range of socio-economic status for the county in which they were based. The INT group 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 PE sessions and lasted 30-40 minutes. INT children therefore engaged in one INT and one PE session per week. The CON group did not perform specific INT but attended their two statutory PE classes per week. The PE activities engaged in by the INT and CON groups were the same. Prior to and immediately following the intervention participants in both groups were assessed on process and product measures of FMS, and physical self-efficacy.

Subjects

94 Children (49 boys, 45 girls) from 2 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 = 4) were randomised into either an INT (n = 53) or CON (n =41) 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 (process and product measures) and physical self-efficacy. This process was then repeated on completion of the 10 week intervention period.

Table 1 Here

FMS assessment

Both process and product measurements of motor competence were employed in the present study. In this way we sought to provide a holistic overview of FMS. Process oriented movement skill assessment are concerned with how the skill is performed whereas product oriented movement assessment is concerned with the outcome or product of the skill executions (such as distance jumped, thrown, time, number of successful attempts) (4).

Process measures of FMS

Five motor skills (2 locomotor, 3 object control) were assessed using the Test of Gross Motor Development-2 (TGMD-2) (25). In the current study the following skills were assessed: run, jump, catch, throw, bounce. Each skill comprises 3-5 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 FMS (scored 0-19) score and scores from the run and jump were summed to create a locomotor competence score and the catch, throw, bounce summed to create an object control score following recommended guidelines of administration of the TGMD-2 (25). 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 FMS videos. Both raters has 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 FMSs between the two researchers. Inter-rater reliability was 92.3% and intra-rater reliability was 97.6%, demonstrating good reliability (14).

Product Measures of FMS

Four product measures; 10m flying sprint time, vertical jump height, standing long jump and seated medicine ball (1kg) throw were assessed. A 10-metre sprint run was timed using smart speed gates (Fusion Sport, Coopers Plains, Australia). Two laser gates were set up 10 metres apart, with the participant having a flying start to ensure that sprint speed (Secs) was measured independently of the acceleration phase. Vertical jump height (cm) was measured using a Takei jump meter (Takei Ltd, Japan) and standing long jump using a tape measure. 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 (6). The medicine ball throw was conducted as a measure of upper body strength following procedures reported by Davis et al (6). Children sat on the floor before throwing the medicine ball forwards like a chest pass three times with furthest distance thrown (m) assessed using a tape measure. In a subsample of participants (n = 20), one week test retest reliability was determined. Intraclass correlation coefficients for the four product measures of FMS were .9, .83, .94, and .81, for the flying 10m sprint, vertical jump, standing long jump and seated medicine ball throw respectively.

Physical self-efficacy

Physical self-efficacy was assessed using the Perceived Physical Competence Subscale for Children questionnaire (PPCSC) (11). The questionnaire assesses children's physical self-perception of their own skill competence and comprises 10 questions, each on a 4 point Likert Scale, which ask children to rate their perception of their ability in fundamental movement skills relating to throwing, catching, kicking, aerobic endurance and strength performance. Higher scores are reflective of greater self-efficacy in athletic tasks. The PPCSC has been shown to discriminate between self-efficacy levels in children and has been widely used in the literature (3,8,13). The questionnaire was completed in a classroom with a researcher and a class teacher.

INT Program

The INT program used in the present study was specifically designed for primary school children and was based on earlier reports on resistance training, neuromuscular conditioning and motor development for children of the ages involved in the study (5,9,24). The INT group undertook one session of integrated neuromuscular training, lasting 30-40mins per week, for 10 weeks, in place of one of their normal school PE lessons.

This decision was taken, congruent with studies examining efficacy of school based movement interventions (3, 18), in order to have little disturbance on the school curriculum, to create a design that could be realistically integrated into the school curriculum and to explore a design that would be more likely to be employed in the school setting by teachers. The INT program employed was also designed to be time efficient (fitting within standard PE time), inexpensive and developmentally appropriate. The INT group also undertook a second weekly PE lesson during the intervention period, as part of statutory PE, which was focused on team games

(Hockey and Basketball). The CON group continued their twice weekly statutory PE lessons (Hockey and Basketball) and there was no difference in the delivery and content of the statutory PE lessons for INT and CON groups.

The principal investigator delivered all the INT sessions with the assistance of a primary school teacher. The other PE session for the INT group and PE sessions for the CON group were delivered by the PE teacher and in accordance with guidelines for the National Curriculum for PE in England. The principal investigator documented adherence to the programme and compliance with the INT program. Any child who missed more than 2 INT sessions in the 10 week intervention period was not included in final analysis. This resulted in 3 exclusions from the final data set for analysis (all in the INT group and due to sickness).

The INT program consisted of mobility focused warm up exercises (deep squat, bear crawls), followed by a series of fundamental movement exercises focused on the development of fundamental movement skills. These were based on developmentally appropriate activities (project hop) to enhance locomotor and object control skills in children aged 5-8 years old. Table 2 outlines the structure and content of the INT programme. Similar to other research using INT with children (9), participants in the INT group 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

In order to examine any differences in product and process measures of FMS and physical self-efficacy data were analyzed using a series of 2 (INT vs CON) X 2 (Pre vs Post) X 2 (gender) ways repeated measures ANOVAs. Where any significant differences were found post hoc pairwise comparisons (Bonferroni adjusted) were employed to examine where the differences lay. Partial η^2 was used as a measure of effect size. 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 34 participants per group was required. The Statistical Package for Social Sciences (SPSS, Version 20) was used for all analysis.

Results

Process measures of FMS

Results from repeated measures ANOVA indicated a significant group (INT vs CON) X time (Pre to Post) interaction (F 1, 90 = 1.608, $P = 0.001$, Partial $\eta^2 = .467$, See Figure 1). Bonferroni adjusted post hoc pairwise comparisons indicated no significant difference between total FMS scores for INT and CON groups pre intervention ($P = 0.406$) but significantly higher total FMS scores for INT compared to CON post intervention ($P = 0.001$). There was also significant increases in total FMS pre to post for the CON and the INT group (both $P = 0.001$). However, the change in total FMS for the INT group was significant and greater in magnitude (delta = 5) compared to the CON group (delta = 1.5). Gender was not significant as a between subjects factor (P>0.05).

Figure 1 Here

Product Measures of FMS

Like the results for process measures of FMS, the results from repeated measures ANOVAs for product measures of indicated significant group (INT vs CON) X time (Pre to Post) interactions for 10m sprint time (F 1, 90 = 28.25, P = 0.001, Partial η^2 = .239, See Figure 2), CMJ (F 1, 90 = 21.05, P = 0.001, Partial η^2 = .190, See Figure 3), SLJ (F 1, 90 = 18.7, P = 0.001, Partial η^2 = .143, See Figure 4) and MBT (F 1, 90 = 19.8, P = 0.001, Partial η^2 = .180, See Figure 5).

10m Sprint Time

For 10m sprint time, post hoc analysis indicated significant differences in sprint time between INT and CON groups at pre (P = 0.001) with the INT group being slower than the CON group. There was however no significant difference (P = 0.161) in 10m sprint time between INT and CON groups at post intervention. Consequently, sprint time significantly decreased pre to post for the INT group (P = 0.0001) but not for the CON group (P = 0.324).

Figure 2 Here

Counter Movement Jump

Post hoc pairwise comparisons for CMJ height indicated no significant differences in CMJ height between INT and CON at pre ($P = 0.159$) but significantly greater CMJ height for INT, compared to CON ($P = 0.0001$, diff = 4.2cm) post intervention. CMJ height significantly increased for INT ($P = 0.0001$) but not CON ($P = 0.948$) pre to post.

Figure 3 Here

Standing Long Jump

A similar trend to that describe for CMJ was evident for SLJ. There was no significant difference in SLJ between INT and CON groups at pre but significantly greater SLJ for INT compared to CON ($P = 0.006$, diff = 0.6m) post intervention. However, SLJ significantly improved pre to post for both the INT ($P = 0.001$, delta = 0.13m) and CON ($P = 0.01$, delta = 0.05m) groups.

Figure 4 Here

Medicine Ball Throw

In regard to MBT there was significantly higher MBT scores for INT compared to CON pre intervention (P = 0.001, diff = 0.4m) and post intervention (P = 0.0001, diff = 0.57m). MBT distance significantly increased pre to post for CON (P = 0.043) and INT (P = 0.0001) with the magnitude of chance being greater for INT (delta = 0.28m) compared to CON (delta = 0.11m).

Figure 5 Here

Physical self-efficacy

Results from repeated measures ANOVA for physical self-efficacy indicated a three-way, group (INT vs CON) X time (pre vs post) X gender ways interaction (F 1,89 = 14.85, P = 0.001, Partial η^2 = .143, See Figure 6).

Figure 6 Here

Post hoc analysis indicated that there were no differences in PPCSC scores for boys in INT and CON groups pre intervention (P = 0.823) but boys in the INT group had significantly higher PPCSC scores post intervention compared to boys in the CON group (P = 0.03). There was no significant difference in PPCSC scores for girls in INT and CON groups pre (P = 0.08) or post (P = 0.07) intervention. There was also no difference between boys and girls in the INT group pre intervention (P = 0.221) but PPCSC scores were significantly higher for boys in the INT group, compared to girls in the INT group post intervention (P = 0.04). For the CON group, pre intervention boys had significantly higher PPCSC scores than girls (P = 0.002). At post intervention this significant difference remained (P = 0.023) although PPCSC scores for boys in the CON group had declined resulting in a smaller difference between boys and girls in the CON group post intervention, compared to pre intervention values.

Discussion

The results of this study demonstrate the efficacy of including an integrated neuromuscular training program within primary school and suggest that 10 weeks of INT produces positive changes in both process and product measures of fundamental movement skills in children aged 6-7 years old. The changes observed in the current study were superior to those seen in children who undertook a 10 week period of statutory PE. This is the first study to date that has employed integrated neuromuscular training in children of this age and in schools in a way which is practically useable by primary school teachers. As such the results of the current study are novel and extend the work of prior researchers that have advocated the use of INT in children (9, 17). The improvements in both process and product measures of FMS reported in the present study are evidence of the treatment's (INT) efficacy. 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 PE. Moreover, the use of such an approach in 6-7 year old children may provide a stronger athletic foundation for children to build upon using more advanced strength and conditioning type interventions later in childhood.

The results of this study compare favourably to the only other published work documenting efficacy of INT in children (9). Although the work by Faigenbaum et al (9) examined the effect of INT on health related fitness in a slightly older sample than that investigated in the present study, their data identified positive improvements in their studied variables compared to a control group who, like the present study, also undertook statutory PE classes. The results of the current study do align with prior work which evidences that fundamental movement skills can be enhanced via PE based interventions that focus on throwing, catching and locomotor activity (3, 18). However, to the investigators' knowledge this is the first study which demonstrates the efficacy of including INT within school PE

The results of the present study are also comparable with the aforementioned work by Bryant et al (2) in terms of physical self-efficacy changes. Bryant et al (2) reported that a school based FMS program enhanced physical self-efficacy in 8-9 year old children compared to a control group who undertook statutory PE. Enhancing physical self-efficacy in childhood is a key element to child well-being and willingness to engage in a wide range of physical and sports related tasks (11). However, in the current study, physical self-efficacy changes were dependant on gender and group allocation. It appears that boys in the INT group had the greatest increase in self-efficacy pre to post intervention. Physical self-efficacy increased pre to post for girls in both INT and Con groups whereas this went down for boys in the CON group. As children in the CON group were blinded to the activities of those in the INT group (because they were from different schools), it is unlikely that the changes reported here are as a consequence of boys in the CON group being aware they were not allocated to INT. it may be that INT is a more sensitive stimulus for positive psychological change in boys. However, this suggestion is speculative and additional research would be needed to investigate this suggestion. There are a limited number of studies examining the effects of resistance type interventions on psychosocial variables in children (20) making it difficult to draw parallels with the findings of this study and prior research. However, recent meta-analytical data (20) did conclude that differential effects of interventions in boys and girls were evident but that the paucity of data in this area make it difficult to draw any solid conclusions as to why there may be different effects of resistance type interventions in boys and girls.

Importantly the present study not only assessed product measures of FMS (i.e., fitness type measures) but also process measures of FMS. This is important as it suggests that INT can positively enhance movement quality as well as movement outcomes. Such a suggestion and the findings of the current study, also align with the Stodden (22) model of motor development which suggests that early development of competence in FMS will likely increase longer term physical activity participation, reduce unhealthy weight, increase engagement in organised sports and potentially sport performance. The inclusion of INT programmes, such as that trialled in this study, in the English Key Stage 1 curriculum may therefore have multiple positive benefits in for those children who undertake such training. Understanding if there are longer term benefits to participating in such a program was beyond the remit of the current study and future research would be welcome in investigating this issue.

The results of this study should not however be taken that INT should replace PE in primary schools. Rather INT should be seen as complimentary to statutory PE and an activity which explicitly fits the remit of primary school Physical Education Curricula in many countries (1,7,21). This is because INT focuses on motor development and enhancement of the FMS that underpin performance of other more refined sports skills and athletic competence. Therefore, the integration of INT programmes in the primary school PE curriculum should be advocated as an addition to other, more traditional PE activities that currently take place in schools. It could also be suggested that early inclusion of a 10 week block of INT within PE might provide a stronger foundation for subsequent development of sports specific skills through school PE. This would be an interesting future research question.

There are of course some limitations to the current study. The findings reported here are based on a relatively small sample of children from one geographical area of the UK. They are also 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 PE 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. Due to the different developmental trajectories of children through the primary school age range, caution should be applied if trying to apply the program trialled in this study to children who are chronologically older than those examined in this study. Likewise, although it is highly likely that the children who took part in the present study were all pre-pubertal, no assessment of maturation was made. Accounting for maturation is important as its impact on motor performance is well established (23), although typically these effects are seen in children from the ages of 9 years and older, hence why maturation was not assessed in the present study.

Nevertheless, researchers should consider assessing or controlling for maturation in future studies examining INT programmes in pediatric participants. It would have been useful to have also followed up the same children 10 weeks post intervention end to examine if the positive changes reported here were maintained. Understanding if the children who undertook the INT program then participated in greater extracurricular or leisure time sport and physical activity compared to the CON group would also have been an interesting research question to examine. INT is also conceptualised as an integrative intervention model which includes multiple components (e.g., strength, balance, power, skill development) (10). It is therefore difficult to assess the contribution of each component in achieving the overall outcomes reported here. Irrespective, the intervention trialled within this study did include the 6 essential components recently recommended for inclusion in INT programmes for pediatric populations (10).

Practical Applications

The results of this study suggest that replacing 1 of the 2 weekly statutory PE lessons with an integrated neuromuscular training program over a 10 week period results in positive improvements in fundamental movement skill quality and outcomes in children 6-7 years of age. It also enhances physical self-esteem in boys. Such changes are not seen to the same magnitude in children who undertook 2 lessons of statutory PE over the 10 week period. Integrated neuromuscular training 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. For school Physical

Education, including strength and conditioning within statutory PE appears to offer positive opportunity for instilling good movement patterns in children for short and potentially longer term benefit relating to both health and academic potential.

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Figure Legends

Figure 1. Mean ± SE of total FMS score pre to post 10 week intervention for Integrated Neuromuscular Training (INT) and Control (CON) groups (P = 0.001 for INT and CON, pre to post).

Figure 2. Mean ± SE of 10m sprint speed (secs) pre to post 10 week intervention for Integrated Neuromuscular Training (INT) and Control (CON) groups (P = 0.001 between INT and CON and pre, P = 0.0001 pre to post for INT).

Figure 3. Mean ± SE of counter movement jump height (cm) pre to post 10 week intervention for Integrated Neuromuscular Training (INT) and Control (CON) groups (P = 0.0001 between INT and CON post intervention, P = 0.0001 pre to post for INT).

Figure 4. Mean ± SE of standing long jump (m) pre to post 10 week intervention for Integrated Neuromuscular Training (INT) and Control (CON) groups (P = 0.006 between INT and CON post intervention, P = 0.001 pre to post for INT and P = 0.01 pre to post for CON).

Figure 5. Mean ± SE of seated medicine ball throw (m) pre to post 10 week intervention for Integrated Neuromuscular Training (INT) and Control (CON) groups

(P = 0.001 between INT and CON pre intervention, P = 0.0001 between INT and CON post intervention, P = 0.0001 pre to post for INT and P = 0.043 pre to post for CON).

Figure 6. Mean ± SE of physical self-efficacy scores pre to post 10 week intervention for boys and girls in Integrated Neuromuscular Training (INT) and Control (CON) groups (P = 0.03 for boys in INT at post intervention compared to boys in CON, P = 0.04 for boys in INT compared to girls in INT post intervention, P = 0.002 for boys compared to girls in CON pre intervention and P = 0.023 for boys compared to girls in CON post intervention).

	INT (n = 53)		CON (n = 41)	
	Mean	SD	Mean	SD
Age (years)	6.43	0.5	6.23	0.7
Height (m)	1.2	0.05	1.17	0.06
Body Mass (kg)	23.7	3.5	22.8	3.7

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

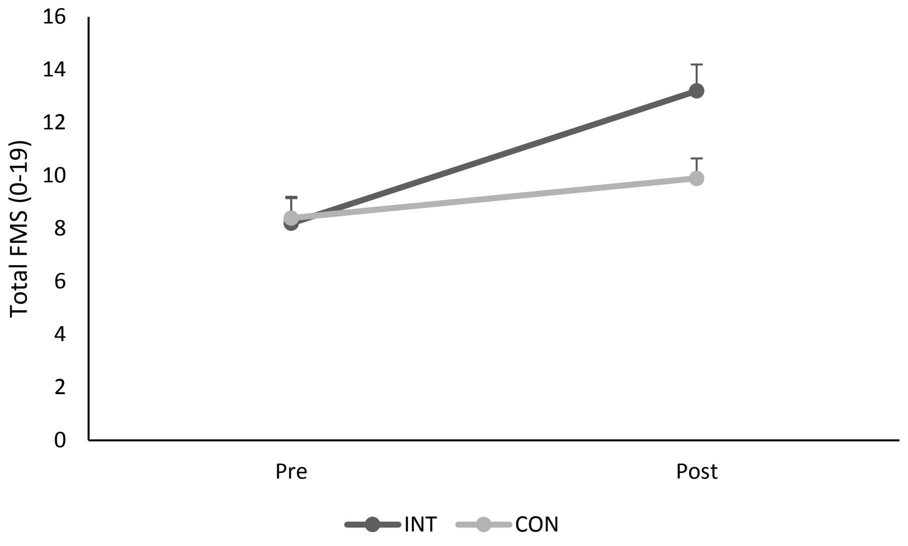


Figure 1.

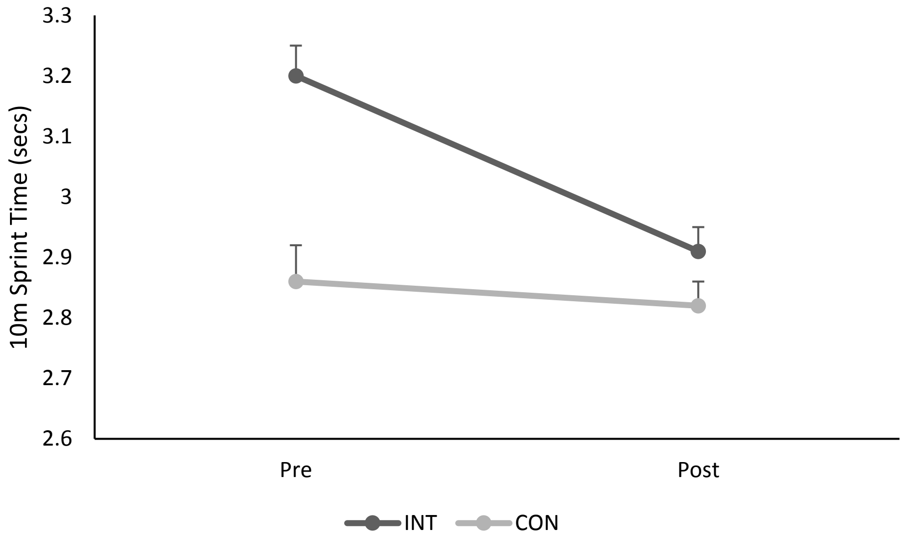


Figure 2.

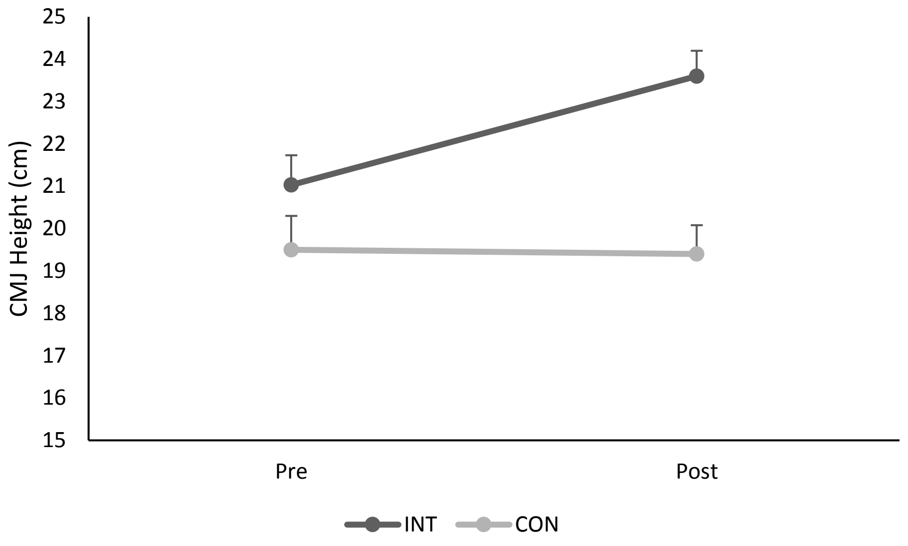
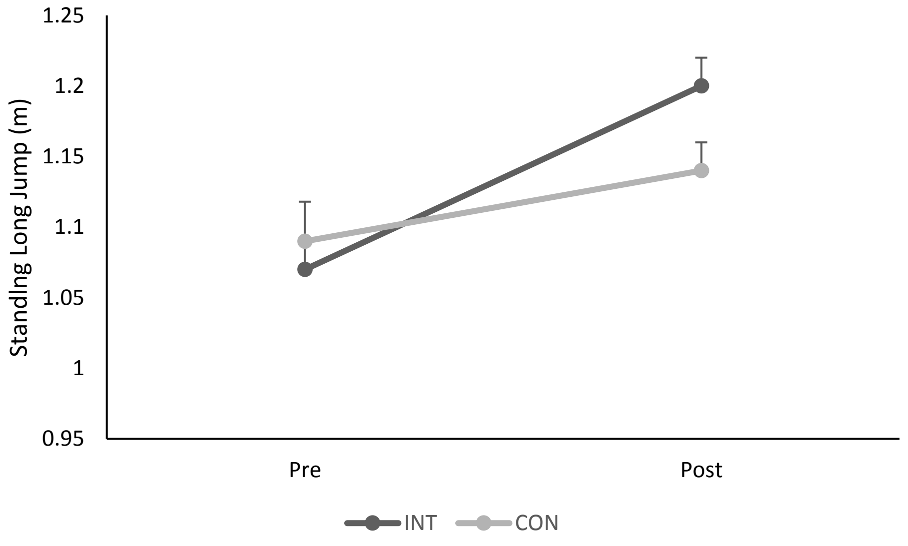


Figure 3.



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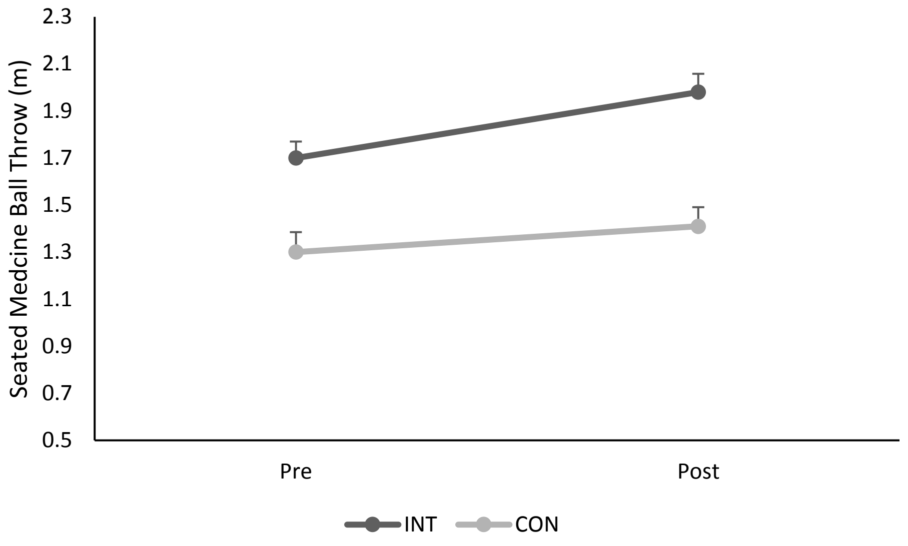

Figure 5.

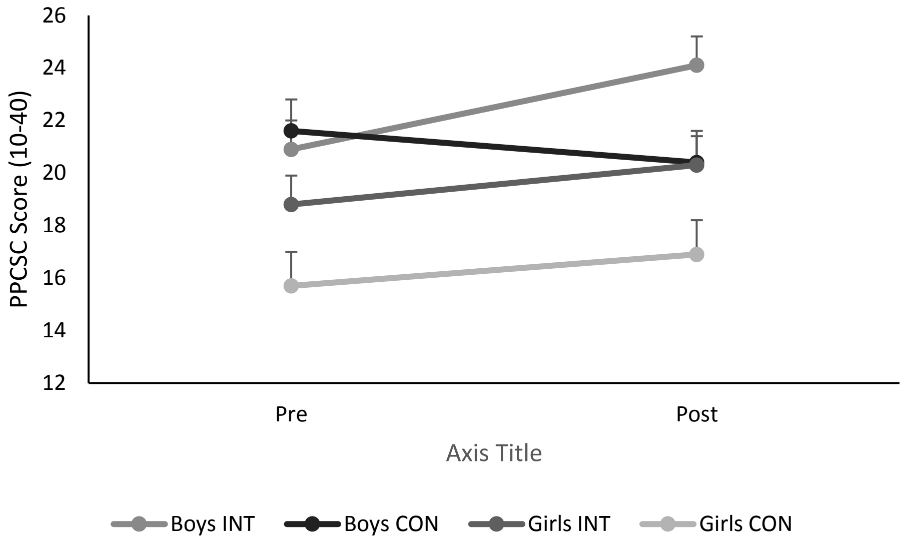

Figure 6.