The effectiveness of four weeks of fundamental movement training on Functional Movement Screen™ and physiological performance in physically active children.

ABSTRACT

The effectiveness of fundamental movement training interventions in adolescents is not fully understood. The Functional Movement Screen™ (FMS) may provide means of evaluating the effectiveness of such programs alongside traditional tests of physiological performance. Twenty-two children completed the FMS, plank, side plank, sit and reach and multi-stage fitness test. Participants were pair-matched by total FMS score and assigned to control or intervention. The intervention group received a weekly, 4 x 30-min training sessions with an emphasis on movement quality while the control group were involved in generic multi-sport activity. A smallest-worthwhile effect of 0.2 between participants SDs was set *a priori* for all measures except total FMS score for which a change of 1 unit was chosen. When compared to the control our intervention had a likely trivial effect for FMS score (0.2 AU; 90% confidence limits ±1.2 AU), a very likely small beneficial effect for plank score (87%; ±55%) but a possibly small harmful effect for side plank score (-22%; ±49%). A likely trivial effect was observed for the sit and reach test (0.3%; ±15%) while the effect of the training intervention on predicted VO_{2max} was unclear (-0.3%; ±11%). Unexpectedly, generic multi-skills activity enhanced both side plank and sit and reach test performance in the control group. These results demonstrated that short-term interventions might affect specific isolated components of fitness but not FMS performance.

Key Words: FMS, core stability, physical education.

INTRODUCTION

Training programs that target fundamental movement quality in young people are an essential component of athletic development to allow safe progression to more complex training (29). Typically these programs focus on flexibility, core stability and neuromuscular control (14). There is strong evidence that fundamental movement training programs can reduce injury rates in athletes competing across a number of sports and a wide range of ages from youth to senior athletes (14,40,48). This is of particular importance in young athletes as high rates of injury have been reported with one-third of school age children sustaining an injury sever enough to require assessment by a doctor or nurse (1). Furthermore, the incidence of serious knee injuries is increasing in this population (1) and a strong case has been made for the development of fundamental movement in reducing such injuries (37).

Kilding et al., (26) showed improvements in leg power after six weeks of performing a fundamental warm-up program (F-MARC FIFA11+). However, it is unclear how these training programs affect other parameters such as core stability, flexibility or measures of athletic performance. Core stability is thought to be an integral part of athletic function (23) and may be important in reducing injury risk (28). Nonetheless, empirical evidence of a link between core stability and athletic performance or functional movement is inconclusive (36,39). The Functional Movement Screen™ (FMS) has become a popular tool used to grade movement capabilities, identify muscle imbalances and predict injury (11,24). Good inter- and intra-rata reliability has been demonstrated previously (32,41,46,50). Studies investigating the effectiveness of the FMS to monitor training interventions have proved inconclusive (e.g. 16). Kissel et al., (25) were able to achieve improvements in FMS score in a group of

professional American football players. Their training program was time and labour intensive with four supervised sessions and two further optional sessions prescribed, thus caution should be made when applying the results outside of professional sport. Two further studies have shown FMS scores to be improved through training interventions (9,19), but neither employed a control group and the effect of any intervention should be measured relative to control. In a larger controlled trial on 60 fire fighters, Frost et al., (16) showed no significant differences in FMS scores after 12 weeks of a training intervention.

Ford et al., (15) highlight some limited physiological evidence for the benefit of fundamental movement and sports skills training on physical literacy in early childhood, e.g. the FUNdamentals stage of long-term athlete development (LTAD). Though it appears unlikely such improvements will be maintained in later stages of development and adolescence. Lloyd and Oliver (29) recommend that fundamental movement skills training programs are incorporated throughout athletic development but are currently not provided as part of the secondary school physical education curriculum in England. In this environment curricular and extracurricular sporting commitments take presidency and time available for such an intervention is limited. Given the potential benefits of fundamental movement training in youths, time-efficient programs with a strong empirical evidence base are required.

To our knowledge, there are no controlled trials investigating the effect of fundamental movement training on FMS scores in young athletes. Giles (18) has developed commercially available exercise guidelines targeting fundamental movement skills throughout stages of LTAD yet their effectiveness has not been

empirically tested. Furthermore, there is very little evidence to demonstrate the effectiveness of fundamental movement skills training on flexibility or core stability in adolescence (4,30). The aim of this study was to investigate the effect of a fundamental movement training intervention, on FMS, flexibility, core stability and physiological performance in secondary school children.

METHODS

Experimental Approach to the Problem

A pair-matched design was used to evaluate the effectiveness of a four-week school-based training intervention on the FMS, core stability, flexibility and selected performance measures in adolescent children. The training intervention employed was based on the *movement dynamics* principles outlined by Giles (18) and the coaching of movement quality was fundamental to enhance neurogenesis and likely adaptation (12).

Subjects

Twenty-two individuals (age 13.4 ± 0.9 years; height 162.0 ± 7.8 cm; weight 51.2 ± 9.5 kg) from the 'Gifted and Talented' program from local secondary schools were recruited for the study. Medical questionnaires, informed consent and parental consent were obtained prior to the start of the study and those involved with the research had all undergone a criminal record bureau check. Ethical Approval was obtained from the local University.

Procedures

The FMS consists of seven fundamental movements, Deep Squat, Hurdle Step, In-line Lunge, Shoulder Mobility, Active Straight Leg Raise, Trunk Stability Push Up and Rotary Stability. Each test is scored and a four-point scale (0 to 3) and on tests where left and right side are measured the lowest score is used, giving a total score out of 21 (7,8). Core stability was measured by recording time in a prone plank position (13) and side plank position (33) using a stopwatch. Flexibility was measured using the sit and reach (43) and a multi-stage fitness test (44) was used to predict maximal aerobic capacity (VO_2max).

All participants reported to the first testing session wearing standard physical education uniform (shorts, t-shirt and trainers). Four testing stations were organised and each individual was assigned to begin at a different station. They completed all the tests in a randomised order. Initial testing took place over two, 30-min periods and was performed by the same three testers. The FMS was recorded using two video cameras (Panasonic, NV-GS400) placed in the frontal and sagittal planes and scored later. The prone hold (or plank) exercise was performed with participants instructed to maintain a linear horizontal position. Side hold variations required the participants to maintain a position where an imaginary linear line could be drawn through the centre of their body.

After the testing the FMS was scored separately by two researchers (A and B) on viewing the videos and with the aid of video analysis software (Dartfish Live, Lausanne, Switzerland) any disagreements were re-evaluated and discussed by both researchers until a consensus was made. Individuals were then match-paired (2), based upon total FMS score and assigned to either control or intervention. The

intervention group completed a four-week movement based program and the control group performed generic multi-sports activity. Testing sessions were carried out one week prior to the intervention and one week post. After the testing, FMS videos were collated and randomised by researcher A. In an attempt to eliminate inherent bias that could affect internal validity of subjective scoring systems such as the FMS, after a four-week wash out period videos were analysed by researchers A and B separately. Researcher B was to be the principle assessor and as thus was not made aware of FMS video order. For reliability purposes researcher B rescreened the videos after a further 4 weeks.

Training Intervention

The training intervention was conducted in the school luncheon break, consisting of nine exercises using body weight or resistance bands and was led by Researcher A. Each exercise could be progressed through varying levels of difficulty (Table 1). All participants started at level 1 and were progressed when they could consistently perform the exercise correctly. Specific sets or repetitions were not prescribed for the exercise as the focus was on quality of execution and not achievement of an external load. Approximately three minutes was assigned to each exercise and the time was divided into activity, coaching and feedback on an individual basis. The focus on quality here is critical as the aim of functional movement training is to induce central nervous system adaptations to enhance timing and activation of agonists, antagonist, fixators and synergists within functional tasks (45). Training load was quantified directly after training using a modified Rate of Perceived Exertion (RPE) scale and session duration (17).

The control group was engaged in multi-sport activities that replicated physical education curriculum, focusing on generic sport or games skills rather than the underlying fundamental movements. Training load was also quantified within these sessions.

Table 1 Here

Statistical Analyses

Data are presented as the mean ± SD. The weighted kappa statistic was calculated for each FMS test (left and right measures were recorded) to determine intra- and inter-rater reliability. The weighted kappa score was used as this method reflects the degree of disagreement between raters by attaching greater emphasis to large differences between ratings than small differences (47). Prior to all further analyses our outcome measures, with the exception of the total FMS score, were log transformed and then back transformed to obtain the percent difference, with uncertainty of the estimates expressed as 90% confidence limits (CL), between the post and pre-tests. This is the appropriate method for quantifying changes in athletic performance (21). All analyses were performed using the analysis of a pre-post parallel-groups controlled trial with adjustment for a predictor spreadsheet (21). This sheet enabled us to use the pre-test score as a covariate to control for imbalance in our measures between the control and intervention groups at baseline (51). We quantified (as a SD) individual differences in response to the intervention, which are frequently highly variable; a negative value indicates more within-subject variation in the control group than in the intervention group (21). Effects were evaluated for practical significance by pre-specifying 0.2 between-subject SDs as the smallest worthwhile effect (5) for all outcomes measures with the exception of total FMS score. We selected a change in 1 unit (AU) for the

total FMS score as our smallest worthwhile effect as it was deemed clinically important given this could take someone either side of the threshold (>14) where a subject maybe more likely predisposed to injury (24,38).

Inference was then based on the disposition of the confidence interval for the mean difference to the smallest worthwhile effect; the probability (percentage chances) that the true population difference between trials was substantially beneficial, harmful (>0.2 SDs) or trivial was calculated as per the magnitude-based inference approach (3). These percentage chances were qualified via probabilistic terms and assigned using the following scale: <0.5%, most unlikely; 0.5–5%, very unlikely; 5–25%, unlikely; 25–75%, possibly; 75–95%, likely; 95–99.5%, very likely; >99.5%, most likely (20). Magnitude-based inferences were then categorised as clinical for all outcome measures as an intervention can be potentially harmful as well as beneficial. The default probabilities for declaring an effect clinically beneficial are <0.5% (most unlikely) for harmful and >25% (possibly) for benefit; a clinically unclear effect is therefore possibly beneficial (>25%) with an unacceptable risk of harm (>0.5%) (20).

Table 2 Here

RESULTS

Descriptive data for both study groups are displayed in Table 2. Intra-rater reliability (Table 3) ranged from fair to almost perfect on the 7 FMS tests. The range of agreement was greater for inter-rater reliability (slight to almost perfect). The effects of our 4-week functional movement training program, after controlling for pre-test scores, are displayed in Table 4. Higher session RPE loads were recorded in the

control (1215 ± 51.0) than those in the intervention (907.5 ± 52.3) throughout the study (Figure 1). We observed a likely trivial effect on the total FMS score, with the SD of the individual response being -1.5% (90% confidence limits ±1.6%). The effect of the training on core strength/stability was a very likely beneficial effect on the plank test (SD of the individual response 29%; ±53%) but a possibly harmful effect on the side plank test (SD of the individual response -5.5%; ±53%). A likely trivial effect was observed for performance on the sit and reach test, with the SD of the individual response being 12.2% (±20%). The effect of the functional movement training program was unclear for predicted VO_2max (SD of the individual response -4.9% ±12%).

Table 3 Here

Table 4 Here

Figure 1 Here

DISCUSSION

This is the first controlled trial utilizing the FMS to assess movement competency in secondary school children. The FMS demonstrated acceptable inter- and intra-rater reliability. The four-week training intervention made little impact on total FMS score, yet did improve core stability, assessed by the plank test. Conversely, a possible harmful effect was found on core stability when assessed by the side plank test. The effect upon predicted VO_2max was unclear and a likely trivial effect was found for flexibility. An improvement was found in sit and reach test in both intervention (13 ± 22) and control (12 ± 18) groups. These results provide some support for the use of fundamental movement interventions however; adaptations to the short-term

intervention are localized and highly specific to the training stimulus. It is possible that the control group derived unanticipated adaptations in flexibility and core stability. These findings also raise questions about the ability of the FMS to detect subtle changes in movement over time, particularly in adolescent populations.

The only previous study assessing FMS performance in this population (35) found a 17% increase in FMS performance in boys, but no change in girls after a six-week intervention aimed at improving dynamic balance and core stability. Yet, these findings are difficult to interpret due to no control group and that the methodological detail presented was scant. Furthermore, no data has been published previously to the reliability of the FMS in children or adolescents. Thus, the current study employed a robust methodology to evaluate the four-week training intervention incorporating inter- and intra-rater reliability measures.

The inter- and intra-rater reliability was comparable to studies in adult populations (32,41,50). Consistent with previous studies (32,50) Rotary Stability demonstrated the lowest agreement while both Trunk Stability Push Up and Rotary Stability demonstrated lower reliability than the comparable literature in adult populations. These tests are used to assess whole body postural control in three-dimensions. Deviations about the longitudinal axis may be more difficult to assess from frontal and sagittal plane video and kappa scores have been stronger in real time (41) than via video (32). Furthermore, three-dimensional postural-kinetic control is developed throughout maturation and as such variability in execution may be greater between repetitions on this type of task in adolescents (49). The appropriateness of Rotary Stability in pediatric populations is a topic for further research.

The training program did improve core stability, assessed by the plank test, yet this did not transfer to an improvement in total FMS score. These findings are similar to those of Moreside and McGill (31) who demonstrated improvements in isolated hip joint range and core endurance after a six-week intervention but this did not translate to changes in motor execution or hip mobility during functional tasks. These data suggest that relatively short intervention periods (i.e. four to six weeks) can only influence isolated components of fitness such as core stability. Transfer to more complex movement patterns, where repetition is necessary to effect change in motor learning (27) may require longer-term interventions. Similarly, Padua et al., (42) demonstrated greater retention of movement pattern changes in landing tasks after a nine-month intervention compared with a three month period in youth soccer players.

Despite only finding a trivial effect for FMS score, had the individual variation in change scores been greater in the intervention group then it would indicate the training program was beneficial in some participants. However, the SD of individual responses was negative showing that there were greater individual differences in the control group. Frost et al., (16) reported a similar result in the only other controlled trial to date, finding greater variation in each of the sub-tests in their control group of firefighters. Taken together these results raise concerns over the effectiveness of the FMS to monitor changes in movement execution over time. In particular the influence of repetition-to-repetitions and day-to-day variability in test execution could have affected the results. Alternatively, improving movement consistency may be of importance in practice, as joint kinetic variability itself has been proposed as a risk

factor for sustaining an injury (22). A reduction in the variability in how an FMS test is performed, independent of an enhanced score, may be beneficial.

The effects of the training program on core stability were contradictory; a likely beneficial effect was found for plank score yet the converse effect on side plank. The increase in plank score most probably reflects the specificity of the loading in the intervention. The training intervention focused on educating the participants to brace and control the spine with exercise that primarily load in either the frontal or sagittal planes of movement. Almost all the intervention exercises include some form of single plane stability and direct derivatives of this test were incorporated within the training program. The side plank is a more advanced test with a narrower base of support, which challenges the body to provide stability against rotation in all three planes of movement. This stability is provided through the muscles of the abdominal wall and the quadratus lumborum that can be activated up to 50% of maximal voluntary contraction (34). The control group who were involved in generic multi-sport activity, typical of Physical Education classes, enhanced their side plank score. These activities stress the body in all three planes of movement and whilst not chosen intentionally to do so, may have been ideal for enhancing multi-planar stability. It is likely that the nature of adaptation in core stability is very specific to the stimulus, in particular the direction of forces acting upon the body.

The exercise progressions in the intervention group (Table 1) focused on the progressive development of movement quality and control. The principles of progressive loading from low-level single plane exercise to multi-planar progressions were followed (6,18). With a relatively low mean FMS score (12AU) all exercises

had to be regressed to their most basic level, with a focus upon educating the participants to perform the correct technique before any progressions were allowed. Whilst, Cook (6) recommends the FMS is use to individualised training programs based on the subject's "weakest link" this was not practical and a group based approach taken. The educational element of the training intervention was felt to be crucial because of the purported benefits of mentally stimulating exercise on neurogenesis (12). Unfortunately, this approach may have contributed to a reduced session RPE load (Figure 1) in the intervention group throughout the study. Session RPE load was also lowest in the first week and increased each week thereafter supporting the effect of teaching and learning on loading (i.e. as the participants understood, and were able to progress the exercises, the overall load subsequently increased).

It was not the intension of this study to examine the effects of generic multi-sport activity however, both side plank and flexibility improved in the control group. The improvements to flexibility are interesting given that neither intervention nor control group performed static stretching exercises. This could be a practically significant finding as flexibility is often reduced in athletes sustaining lower limb injury yet paradoxically stretching programs which increase flexibility have been shown to be ineffective in injury prevention [28, 39]. It is possible that the mechanism driving this response was an increase in eccentric strength. A recent systematic review found eccentric strength training interventions increased fascicle length and range of motion [39]. In the current study elements of eccentric strength and control were evident in both groups. The intervention provided a controlled and systematic progression of bodyweight strength development and in the control group dynamic eccentric loading

was more random and chaotic in nature, yet a response was observed with both approaches.

The nature of the loading in generic multi-sport activity may be similar to the principles of Integrated Neuromuscular training which has been shown to have a positive effect on the mechanisms of anterior cruciate ligament injuries (37). The specific nature of the adaptations in core stability tests question the appropriateness of providing highly controlled and progressive exercise interventions alone. Training programs that combine well coached exercises with a specific focus on movement quality, alongside more traditional multi-planar activities maybe time-effective and ideally suited to youth populations. This should be a focus for further research studies.

PRACTICAL APPLICATION

This study supports the use of exercise interventions in secondary school children. The use of predominately single plane regressed exercise alone is unlikely to provide sufficient stimuli for young athletes over a short duration however, when compared to generic multi-sport activity it is possible to enhance isolated tests such as the plank and longer duration interventions may be more beneficial (42). Practitioners working in this population may wish to consider the specific changes in both intervention and control group in this study. A combination of both approaches may provide an appropriate training stimulus to bring improvements in flexibility and core stability.

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Table 2 Participant characteristics at baseline

	Intervention (n=11)	Control (n=11)
Age (years)	13.0 ± 0.8	13.8 ± 0.8
Body mass (kg)	51.5 ± 7.3	50.4 ± 9.7
Height (cm)	162.0 ± 3.7	163.4 ± 9.6
Sitting height (cm)	80.6 ± 1.6	82.8 ± 5.2
Total FMS score (AU)	11.9 ± 1.7	12.2 ± 2.1
Plank (s)	40 ± 14	62 ± 40
Side plank (s)	69 ± 26	100 ± 69
Sit and reach (cm)	18.0 ± 7.9	19.6 ± 9.2
Predicted VO_2max (mL·kg^{-1}·min^{-1})	42.0 ± 6.7	37.8 ± 4.4

Table 3 Intra- and inter-rater weighted Kappa scores for the 7 FMS exercises (left and right measures where recorded)

Test	Agreement (%)	Intra-Weighted Kappa	Level of Agreement	Agreement (%)	Inter-Weighted Kappa	Level of Agreement
Deep Squat	76	0.68	Substantial	80	0.75	Substantial
HS (right)	68	0.68	Substantial	60	0.60	Moderate
HS (left)	72	0.69	Substantial	84	0.79	Substantial
ILL (right)	60	0.50	Moderate	60	0.47	Moderate
ILL (left)	76	0.68	Substantial	48	0.45	Moderate
ASLR (right)	80	0.82	Almost Perfect	80	0.83	Almost Perfect
ASLR (left)	80	0.87	Almost Perfect	76	0.82	Almost Perfect
SH (right)	88	0.77	Substantial	96	0.65	Substantial
SH (left)	80	0.43	Moderate	92	0.63	Substantial
TSPU	68	0.43	Moderate	72	0.36	Fair
RSTAB (right)	60	0.26	Fair	52	0.11	Slight
RSTAB (left)	56	0.23	Fair	68	0.34	Moderate

DS = Deep Squat, HS = Hurdle Step, ILL = In-line Lunge, ASLR = Active Straight Leg Raise, SH = Shoulder Mobility, TSPU = Trunk Stability Press Up, RSTAB = Rotary Stability

Table 4 Adjusted change scores (after controlling for the pre-test score) for all outcomes measures, along with practical inferences of the between-group change with reference to the smallest worthwhile change*

	Adjusted change			Likelihood (%) of the
	Intervention mean ± SD	Control mean ± SD	Difference ±90%CL	intervention being beneficial/ trivial/ harmful
FMS (AU)	0.8 ± 1.2	0.6 ± 2.0	0.2 ±1.2	13 / 82 / 5
Plank (%)	46 ± 57	-22 ± 76	87 ±55	97 / 2 / 0
Side Plank (%)	-12 ± 63	13 ± 63	-22 ±49	6 / 26 / 68
Sit and Reach (%)	13 ± 22	12 ± 18	0.3 ±15	9 / 83 / 8
Predicted VO_2max (%)	-3.2 ± 11	-2.9 ± 12	-0.3 ±11	28 / 42 / 31

*   0.2 SD of the pre-test score

CL   Confidence limits

Figure 1: Training load as a product of session duration x RPE 1-10 (Foster, 1998)