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Effectiveness of a 16 week gymnastics curriculum at developing movement competence in children

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Abstract

Objectives: Internationally, children's movement competence levels are low. This study's aim was to evaluate the effectiveness of a 16 week gymnastics curriculum on stability, locomotive and object control skills and general body coordination. It was hypothesised that the gymnastics intervention group would demonstrate significant improvements beyond a PE comparison group.

Design: This study used a non-randomised control design. The intervention and comparison groups were drawn from three primary schools. The study followed the Transparent Reporting of Evaluations with Nonrandomized Designs (TREND) statement for reporting.

Methods: A total of 333 children (51% girls, 41% intervention) with a mean age of 8.1 years (*sd* = 1.1) participated. Intervention children (16 weeks x 2hrs of gymnastics) were compared to children who received (16 x 2hrs) standard PE curriculum. Children's movement competence was assessed using the Test of Gross Motor Development – 2, Stability Skills Assessment and the Körper-Koordinationstest für Kinder. Multilevel linear mixed models, accounting for variation at the class level and adjusted for age and sex, were used to assess intervention relative to comparison differences in all aspects of movement competence.

Results: Stability and object control skills showed a significant ($p < .05$) intervention x time interaction effect. No difference was found in locomotor skills or general coordination.

Conclusions: Gymnastics is effective at developing stability skills and object control skills without hindering the development of locomotor skills or general coordination. Accelerated learning of stability skills may support the development of more complex movement skills.

Keywords: Fundamental Movement Skills, Stability Skills, TGMD-2, KTK, Primary School, Physical Education.

Introduction

The ability to perform various movement skills (e.g. running, kicking, jumping) in a proficient manner is defined as movement competence [1,2] which comprises three discrete constructs [2]: locomotor, object control, and stability skills. Collectively, known as fundamental movement skills (FMS), these are seen as the foundation for more specialised movements required in many sports and physical activities [3]. Mastery of FMS is associated with health benefits [4] and longitudinal evidence suggests children who have better FMS skills are more likely to possess superior cardiovascular fitness at 16 years of age [5]. Typically, interventions designed to improve children's FMS have focused on the development of object control and locomotor skills [6,7]. Consistent with Gallahue et al,[2] recent work has suggested stability skills are a separate construct in the FMS family [8] which currently are not adequately assessed or developed. Typically European assessment of movement competence does not focus on FMS but instead examines children's movement coordination with regard to their ability to undertake novel and unfamiliar gross motor tasks [9]. Collectively, the absence of stability skills and general body coordination, may contribute to a lack of movement competence. Burton and Rogerson [10] argued that practice in physical education (PE) should be consistent with a theoretical model of movement competence and, interventions based in the PE setting should therefore develop and measure all aspects of children's movement competence.

Australian children's have poor stability skills[8], they are significantly behind their Belgian counterparts in general non-sport specific body coordination [11] and they perform poorly in tests of locomotor and object control skills [12,13]. This may be attributed to diminished PE time in schools [14,15] and an increased focus on the development of team sports at the cost of individual sports such as gymnastics [16]. Gymnastics training has been found to produce superior stability skills [8]. A lack of gymnastics training may be a contributing factor for children failing to develop more complex object control skills [17] and having poorly developed general coordination and stability skills [11].The aim of this study was to evaluate the effectiveness of a 16 week gymnastics curriculum developed by Gymnastics Australia (GA) to develop stability, locomotive and object control skills and general body coordination. It was hypothesised that the gymnastics intervention group would demonstrate significant improvements beyond a PE comparison group.

Methods

This study used a non-randomised control design (see Figure 1) as the schools' principals were unwilling to follow this process as it would involve making changes to the schools' timetables. Instead, the intervention and comparison groups were identified by the school principals, although it was requested that they did not select groups based upon judgements of who might benefit most from being involved in the intervention. Classes of children from three primary schools were allocated as intervention or comparison groups. The study followed the Transparent Reporting of Evaluations with Nonrandomized Designs (TREND) statement for reporting. Power analysis, using a medium effect size d = 0.39, taken from the meta–analysis of the effectiveness of motor skill interventions in children [18], indicated that it would require 140 participants in each condition to have 90% power for detecting a medium sized effect when employing the traditional .05 criterion of statistical significance.

<Figure 1 here>

Participant selection was guided by the Socio-Economic Indexes for Areas (SEIFA) Index of Relative Socio-economic Advantage and Disadvantage, developed by the Australian Bureau of Statistics (ABS). One low, one medium and one high socio economic status (SES) school were selected. The study was approved by the lead author's University Ethics Committee and the Department of Education and Early Childhood Development. Children were asked to return written informed consent forms from their parents or guardians, with 89.5% returning the consent forms. This resulted in 333 children (intervention n = 135; comparison n = 198), 51% girls, with a mean age of 8.1 years (SD = 1.1). Two intervention classes were chosen from each school (one from year 1/2; and one from year 3/4) totalling six intervention classes. The remaining eight classes continued with their standard PE curriculum and made up the comparison classes group (four from year 1/2; four from year 3/4).

Movement competence was measured using three test batteries. A stability test battery consisting of the rock, log-roll and back support was used to examine postural stability [8]. These skills were scored individually and summed to produce a stability composite score. The TGMD-2 [19] was used to assess proficiency in six locomotor skills (run, hop, slide, gallop, leap, jump) and six object control skills (strike, dribble, catch, kick, throw, roll). For both the TGMD-2 and the stability skill assessment, skill components were marked as ‘present’ or ‘absent’. The components for the six locomotor skills were then summed to give a locomotor score, and likewise for the object control score and stability score. Non-sport specific body coordination was assessed using the Koorperkoodinatoin test fur kinder (KTK) [20] with four outcome-based subtests; reverse balance (RB, walk backwards on balance beams decreasing in width); hopping for height (HH, hop on one leg over an increasing number of 5 cm foam blocks to a maximum of 12 blocks); continuous lateral sideways jumping (CS, number of sideways jumps with feet together over a wooden slat in 15 seconds); and moving platforms (MP, moving across the floor during 20 seconds using two wooden platforms). These scores were summed to give an overall general movement coordination score.

Height and weight were measured with a Mentone PE087 portable stadiometer (Mentone Educational Centre, Melbourne, Australia) and SECA 761 balance scale (SECA GmbH & Co. KG., Birmingham, UK). Body mass index (BMI) was calculated as weight (kg)/height^2 (m^2). Two measures were taken for height and weight with the average being recorded. Grip strength was assessed with an isometric handgrip dynamometer (TTM Dynamometer, Tsutsumi, Tokyo).

To ensure a high level of reliability a battery of gold standard videos was created for each test and scored by the lead author (JR) and author 6 (RP). To ensure accuracy, authors recoded the videos three times; each iteration achieved the same total score and the scoring was therefore consistent.
Prior to assessments in the field setting, 10 Research Assistants (RAs) received six hours training in testing administration. The six RAs who had been selected to administer the KTK watched a battery of the gold standard videos for each test. RAs scored all children in the videos according to KTK guidelines and their scores were summed to give an overall coordination score. Using percent agreement, all RAs achieved 94% or higher when compared to the gold standard coordination score.

Two RAs were trained to code the 12 TGMD-2 skills, and two were trained to assess the three stability skills. Inter-rater reliability between the RAs and lead author was similarly established through coding gold-standard videos. The RAs and lead author scores were assessed through intra-class correlation coefficients (ICC) prior to testing in the field at pre and again at post. Subtest scores were found to be good for locomotor (Pre - test: ICC = 0.90; 95% CI: 0.73 - 0.98, Post - test: ICC = 0.91; 95% CI: 0.75 - 0.96) , object control (Pre -test: ICC = 0.82; 95% CI: 0.58 - 0.96, Post - test: ICC = 088; 95% CI: 0.70 - 0.97) and stability skills (Pre – test: ICC = 0.82; 95% CI: 0.53 - 0.93, Post- test ICC = 0.90; 95% CI: 0.73 - 0.97).

Twenty five children completed the assessment simultaneously with groups of five rotating around five skill stations (two TGMD-2 and KTK stations, one stability station and one anthropometric station). Each group started and finished at a different station; this ensured the assessment was counterbalanced which guarded against factors such as fatigue influencing the scores. All children wore light sports clothes, and completed the KTK, stability skills and anthropometrics in bare feet. Before the execution of each skill, children watched one live and one pre-recorded demonstration. They had one practice attempt and two assessment trials for each of the stability skills and the TGMD-2 test battery. The KTK was administered according to the manual guidelines [20]. RAs were blind to which classes were in the intervention groups.

For the duration of the intervention period both groups received two hours PE per week for two school terms (16 weeks intervention plus pre- and post-assessment testing during weeks 1 and 18). The intervention group received the gymnastics based PE curriculum taught by a gymnastics coach for the first hour during the first term, shadowed by the classroom teacher. The second hour of gymnastics was taught by the school's PE teacher. During the second term the PE teacher and classroom teacher taught one hour each. The comparison group received two hours of their normal PE curriculum for 16 lessons which comprised team sports with one lesson taught by the PE teacher and one by the classroom teacher (see supplementary material 1).

The gymnastics intervention "LaunchPad" was designed for children up to 12 years of age with three levels of resources: KinderGym (2-5 years); GymFun (5-7 years); and GymSkills (8-10 years). All lessons have five teaching stages and follow a set sequence: warm-up, brain challenge, main activity, circuit, and cool down. Each stage contains clear content descriptors of what should be taught and a recommended timeframe. Each set of resources contains chronological lesson plans, with each lesson building upon the previous one, and skill cards to complement the lesson plans (see supplementary material 2). In total, 192 gymnastic lessons were delivered, with 10% (a total of 20) observed to ensure the fidelity of the instructor (PE teacher, class teacher or coach) delivering the lesson as intended. This involved the RA coding: a) whether all five stages of the LaunchPad lesson plan were covered, with a score of one awarded for each stage; and b) whether the instructor delivered each of the five sections in the appropriate time frame +/- 2 minutes, with, a score of one awarded for each stage. These two scores were summed to give a total lesson fidelity score out of 10.

Statistical analyses were performed using MLwiN 2.33 and SPSS. To examine the fidelity of the LaunchPad curriculum delivery, two one-way ANOVA's were conducted (lesson content and lesson timing), with instructor type (PE teacher, class teacher and coaches) and school as independent factors.

To examine the effect of the gymnastics based PE intervention a series of multilevel linear mixed models were used with the fixed factors condition (intervention vs. comparison), sex and age. The outcome variables in the respective models were 1) stability, 2) locomotor, 3) object control and 4) general body coordination (KTK). Class and child were random factors. The fixed effect of this variable was expressed by the regression coefficient. Grip strength and BMI were included in the original models but were found to be non-significant predictors in all of the models and, as such, they were removed as predictors from the results for clarity.

To determine the hierarchical nature of the data, the relation between random intercept effects using intra-class correlation (ICC) to compare the variation between class and child as a fraction of the total variance were investigated. For the post intercepts only model, three sets of regression models were constructed. Model 1 included sex (dummy variable male) as a predictor, model 2 included sex and chronological age in months as a predictor and model 3 included sex, age and treatment by time interaction effect (dummy variable intervention). To assess overall model fit the 2*loglikelihood measure was used. This measure will decrease if independent variables have improved the ability to predict the dependent variable accurately. To assess if this was a significant or trivial improvement in the ability to predict the dependent variable, the difference value between the 2*loglikelihood values in the base model and the model including explanatory variables was calculated using the Chi-Square statistic.

Results

Retention rate at post-test was 93% (see Figure 1). The absent children were similar to the remaining participants in terms of sex, age, locomotor, object control, stability and body coordination performance (all $p > .05$). Participating children's mean scores for locomotor, object control, stability skills and general body coordination split by condition are shown in Table 1.

<TABLE 1 HERE>

There was no significant difference between coaches', teachers' and PE teachers' adherence to delivery of the lesson plans ($F(2,17) = 0.16$; $p = .85$; $\eta^2p = .02$) and no significant difference between the three schools in how the teachers, PE teachers and coaches delivered the intervention ($F(1,17) = 0.73$; $p = .49$; $\eta^2p = .08$).

The gymnastics intervention group showed a significant improvement relative to the comparison group in stability and object control ($p < .05$), but not in locomotor ($p > .05$) skills (See Table 2). Sex was not found to be a covariate in the stability skills model. Sex was a significant covariate in the locomotor model with girls demonstrating greater improvement than boys. Also, boys improved significantly more than girls on object control skills. Age was not found to be significant for stability or locomotive skills but was found to be a significant covariate for object control skills with younger participants showing larger gains. Model fit for stability, object control and locomotor skills showed a significant improvement with the inclusion of the gymnastics intervention compared to the intercepts-only model (stability X^2 (Δ 3 df) = 183 $p < .001$) (locomotor X^2 (Δ 3 df) = 154, $p < .01$; object control X^2 (Δ 3 df) = 213, $p < .001$).

The gymnastics intervention group did not show a significant improvement relative to the comparison group in general body coordination (p > .05) (see Table 2). Sex was found to be significant covariate, with girls performing better than boys on the test battery, whilst age was not found to be a significant covariate. However, overall model fit for general body coordination showed a significant improvement with the inclusion of the gymnastics intervention (general body coordination X^2 (Δ 3 df) = 174 $p < .001$).

<TABLE 2 HERE>

Discussion

The aim of the study was to examine the effectiveness of the gymnastics curriculum in developing movement competence in children in grades 1- 4. Children participating in the gymnastics curriculum showed significantly larger improvements in stability skills and object control skills, but not in locomotive skills and general body coordination, which was contrary to our expectations that all aspects of motor competence would improve. The larger improvements in stability skills, relative to the comparison children, might be due to the fact that stability skills are tightly coupled with the sensory system. Children of primary school age possess mature feedback process capabilities to maintain balance, but the feedforward mechanism, which allows them to integrate and downgrade certain sensory inputs during performance, is immature throughout childhood [21]. In line with previous findings [25] this study provides evidence that a gymnastics based PE curriculum can improve dynamic balance behaviour.

The gymnastics curriculum also resulted in greater improvements in object control skills. Whilst not specifically targeting object control skills, the accelerated development is important due to the positive association between object control skills, physical activity and fitness outcomes later in life [5,22,23]. Object control skills may be more difficult to improve than locomotive skills due to greater skill complexity and perceptual demand [24]. The superior development of stability skills may have contributed to greater perceptual capacity. In particular, improved integration of a feedforward mechanism may have led to greater stabilisation and orientation of the body in space, especially during the more complex components which require rotation of multiple body segments and weight transfer during the kinematic chain of skills (e.g. throw). This explanation, is consistent with the suggestion that underdeveloped postural control in children can act as a limiter on learning to catch [25].

No differences were found between conditions for locomotor skills. Importantly, despite the comparison condition engaging in many locomotor activities they did not show a greater improvement in this area compared to the gymnastics intervention group. This suggests that the gymnastics intervention, whilst improving other aspects of movement competence, did not hinder development of locomotor skills. The gymnastics group did not show any significant improvement in general movement coordination tasks relative to the comparison group. This suggests that the KTK tasks and the locomotor skills are more akin to one another than the object control skills and this may explain the lack of improvement.

Skilled performance in PE or a sport activity is the product of a continually evolving dynamical organization of the human body to meet the demands of the environment[26]. This study found that if children participated in a planned PE curriculum for two hours per week over two school terms, this resulted in a significant improvement in movement skill competence regardless of which curriculum. An important issue in Australia, is that PE is not being given priority in the school curriculum in terms of time allocation, or teacher professional development [14,15,27]. These seem to be restraining factors in terms of developing children's movement competence. Furthermore, this study has highlighted that two hours of quality PE, in the form of a gymnastics-based curriculum, can lead to improved stability and object control skills beyond that of the standard PE curriculum.

It could be argued that the gymnastics intervention resulted in only marginal improvements in stability and object control skills compared to the control group. This may be due to the active nature of the control group's curriculum or the relatively short dose/duration of the intervention. However a key strength of the gymnastics intervention lies in its sustainability as it can be delivered by class teachers within the normal PE timetable. We therefore believe this study provides important, novel information about how movement competence in children might be improved.

The study has a number of limitations. First, it was not possible to randomise class allocation which could have led to bias in class selection. Secondly, the study examined the immediate effects of the intervention [29]. Ideally, follow-up assessments could identify whether the improvement in stability skills impact upon other areas of movement competence. Finally, it would be interesting to examine whether the enhanced movement competence influences physical activity patterns of the children in the short and long-term [30].

Conclusion

This study demonstrated that a gymnastics-based PE curriculum has an accelerated effect on movement competence in comparison to a standard PE curriculum. This was indexed by larger gains in stability skills and object control skills. In addition, following a period of coach shadowing, the gymnastics curriculum was taught by the regular classroom teacher suggesting this model is sustainable and could be implemented on a larger scale.

Practical Implications

- Provides evidence that gymnastics is an essential part of the PE curriculum as it develops stability and object control skills at a faster rate than a standard PE curriculum.
- Gymnastics accelerates a child's object control skills which is important as these skills are associated with physical activity and fitness later on in life.
- Using coaches and class teachers working together provides a complementary synergy of content (coach) and pedagogical knowledge of child learning (class teacher).

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Figure 1: CONSORT flow diagram

Table 2: Effect of a gymnastics intervention on all aspects of FMS stability, locomotor, object control skills and general motor coordination controlling for sex and age (intercept and model 3 displayed in this table)

	Stability Skills				Locomotive Skills				Object Control Skills				General Motor Coordination			
Fixed Part	**β**	**SE**	**β**	**SE**	**β**	**SE**	**β**	**SE**	**β**	**SE**	**β**	**SE**	**β**	**SE**	**β**	**SE**
Intercept (cons)	14.6**	0.4	3.4	1.6	30.4**	0.5	19.6**	2.4	30.7**	1.0	8.5**	2.7	18.7**	2.4	9.0	8.9
Sex (male)			-1.5				-3.1*	0.5			3.8*	0.5			-2.8*	1.5
Age			1.4				1.3	0.3			2.9**	0.3			1.4	1.0
Treatment*Time (intervention)			1.6*	0.3			0.7	0.4			2.0*	0.5			1.9	0.9
Random Part intercept	**Intercept**		**Treatment* Time**		**Intercept**		**Treatment * Time**		**Intercept**		**Treatment* Time**		**Intercept**		**Treatment * Time**	
	σ^2	**SE**	**σ^2**	**SE**	**σ^2**	**SE**	**σ^2**	**SE**	**σ^2**	**SE**	**σ^2**	**SE**	**σ^2**	**SE**	**σ^2**	**SE**
Class level variance	2.3	1.1	1.3	0.5	2.4	1.3	1.3	0.8	14	5.6	5.9	2.5	71.1	29.6	65.4	27.8
Pupil level variance	22.7	1.3	20.8	1.1	41.1	2.3	39.3	2.3	47.3	2.7	40.7	2.3	350.1	19.8	350.5	20.1
ICC	0.09		0.03		0.08		0.03		0.23		0.13		0.17		0.16	

** P = 0.01   * P = 0.05

Table 1: Descriptive statistics [Means and standard deviations (M ± SD)] of movement competency measurements stratified by intervention, sex and pre/post testing.

Variables	Intervention												Comparison											
	Boys						Girls						Boys						Girls					
	Pre			Post			Pre			Post			Pre			Post			Pre			Post		
N	*69*			*63*			*66*			*59*			*102*			*99*			*96*			*89*		
	M		*SD*	*M*		*SD*	*M*		*SD*	*M*		*SD*	*M*		*SD*	*M*		*SD*	*M*		*SD*	*M*		*SD*
Stability	11.7	±	5.2	17.3	±	4.8	13.9	±	5.2	18.3	±	3.7	12.0	±	4.8	15.0	±	3.8	13.6	±	4.8	16.8	±	3.6
Locomotor	28.3	±	6.3	31.2	±	7.3	31.0	±	6.1	32.3	±	5.3	28.0	±	7.2	30.5	±	7.2	30.4	±	5.9	32.2	±	5.6
Object Control	30.0	±	8.5	34.6	±	6.7	27.0	±	7.0	32.6	±	5.8	32.0	±	7.8	34.6	±	7.0	26.6	±	7.4	31.3	±	6.6
General Motor Coordination	146.3	±	46.2	168.8	±	53.4	144.4	±	44.6	170.1	±	48.8	144.4	±	47.4	159.1	±	46.9	141.8	±	35.8	159.7	±	40.9

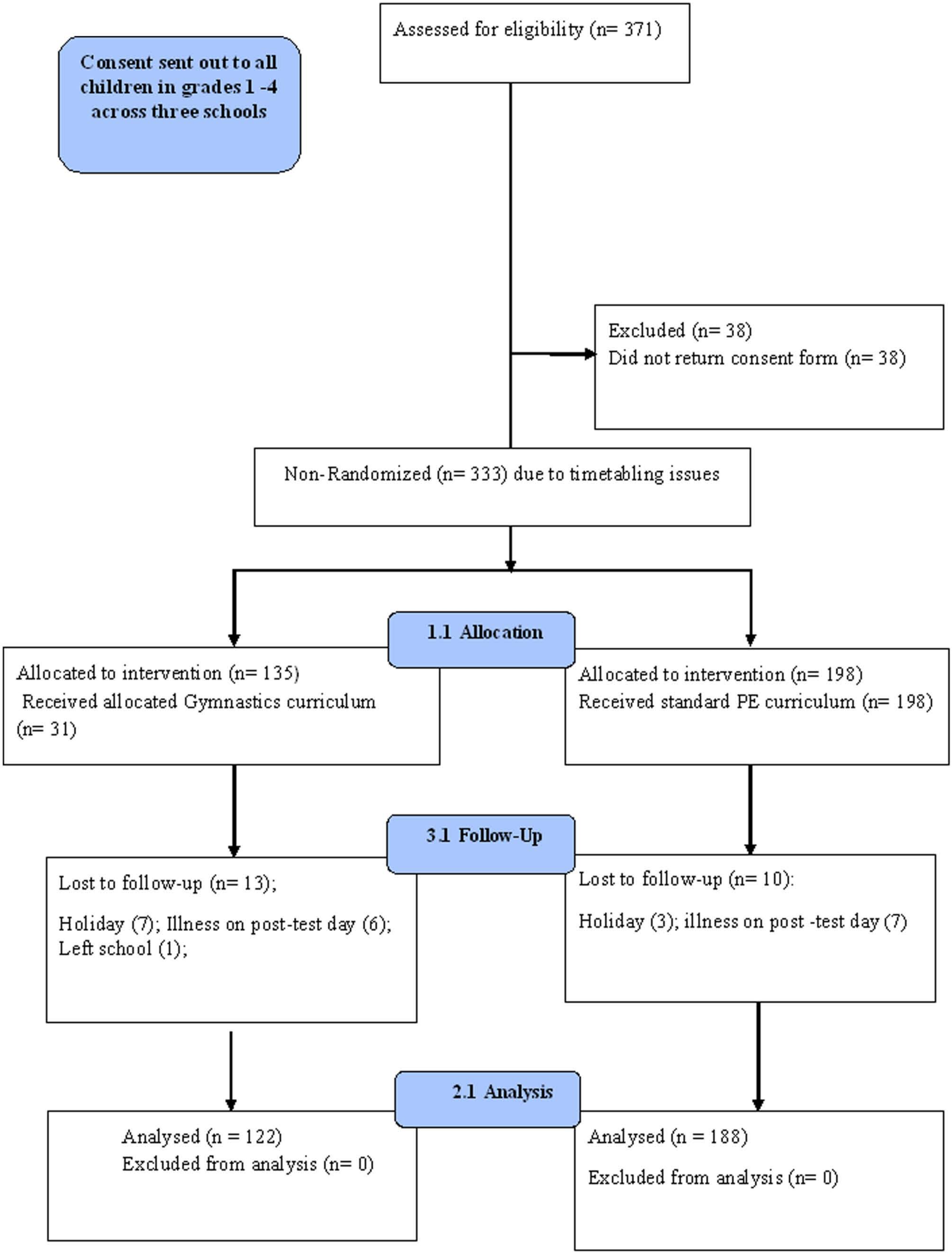

Figure 1: Consort Flow Diagram