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The Impact of a Daily Object Manipulation Warm-Up on Motor Proficiency in Grade 4 Students

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Abstract

Object manipulation skills (OMS) are a key component of motor proficiency and physical literacy, strongly associated with lifelong physical activity (PA). Delays in OMS development can hinder movement competence and confidence, reducing opportunities for participation. This study evaluated the impact of a school-based physical education warm-up targeting OMS on the motor proficiency of Grade 4 students in Alberta. A warm-up format was intentionally chosen as structured pre-lesson routines have been shown to enhance neuromuscular readiness, increase attention, and improve engagement during subsequent PA. By embedding OMS practice in a brief, focused routine at the start of class, students could better prepare for more complex skills during the main physical education (PE) session. Using a single-group pre-post design without a control group, 48 students (28 boys, 20 girls) completed a six-week, 10-minute daily routine of developmentally appropriate throwing, catching, striking, and kicking activities. Motor proficiency was assessed using the Test of Gross Motor Development–Third Edition (TGMD-3), the Bruininks-Oseretsky Test of Motor Proficiency–Second Edition (BOT-2), and the Canadian Agility and Movement Skill Assessment (CAMSA). Significant improvements were observed across all measures, BOT-2 ($p = .003$, $d = 0.45$), TGMD-3 ($p < .001$, $d = 0.84$), and CAMSA ($p < .001$, $d = 1.32$), with both boys and girls demonstrating gains and the gender gap narrowing. Findings support embedding inclusive OMS routines into scheduled PE.

Keywords: physical education; motor development; object manipulation; children

Résumé

Les habiletés de manipulation d'objets (HMO) sont un élément clé de la motricité et de la littératie physique, étroitement liées à la pratique d'une activité physique tout au long de la vie. Un retard dans le développement des HMO peut nuire à la compétence motrice et à la confiance en soi, réduisant ainsi les possibilités de participation. Cette étude a évalué l'impact d'un échauffement en éducation physique, en milieu scolaire et ciblant les HMO, sur la motricité d'élèves de 4e année en Alberta. Le choix d'un format d'échauffement s'est fait délibérément, car il a été démontré que des routines structurées avant les cours améliorent la préparation neuromusculaire, augmentent l'attention et favorisent l'engagement lors des activités physiques subséquentes. En intégrant la pratique des HMO dans une routine brève et ciblée en début de cours, les élèves pouvaient mieux se préparer à des habiletés plus complexes pendant la séance principale d'éducation physique. Selon un plan expérimental pré-post sans groupe témoin, 48 élèves (28 garçons et 20 filles) ont suivi, pendant six semaines, une routine quotidienne de 10 minutes comprenant des activités de lancer, d'attraper, de frapper et de donner des coups de pied adaptées à leur développement. Les habiletés motrices ont été évaluées à l'aide du Test de développement de la motricité globale – troisième édition (TGMD-3), du Test de motricité de Bruininks-Oseretsky – deuxième édition (BOT-2) et de l'Évaluation canadienne de l'agilité et des habiletés motrices (CAMSA). Des améliorations significatives ont été observées pour toutes les mesures : BOT-2 ($p = 0{,}003$, $d = 0{,}45$), TGMD-3 ($p < 0{,}001$, $d = 0{,}84$) et CAMSA ($p < 0{,}001$, $d = 1{,}32$). Les garçons et les filles ont progressé et l'écart entre les sexes s'est réduit. Ces résultats soutiennent l'intégration de routines inclusives de manipulation d’objets dans les cours d'éducation physique.

Mots-clés: éducation physique; développement moteur; manipulation d'objets; enfants

Introduction

The development of functional motor abilities, such as object manipulation skills (OMS), can play a significant role in a child's physical, social, and cognitive development (Stodden et al., 2008; Barnett et al., 2016). OMS, such as throwing and catching, are foundational for children's ability to participate in physical activities, which in turn support cognitive, social, and academic growth (Robinson et al., 2015; Lees & Hopkins, 2013). According to the Canadian Institute of Child Health (2012), Canadian children engage in insufficient physical activity (PA), which is compounded by insufficient emphasis on motor skill development in the physical education (PE) curriculum. Studies suggest that when Canadian children fail to achieve age-appropriate motor proficiency, it results in weaker PA participation that negatively impacts all domains of development (Sallis et al., 2000; Yang et al., 2006; Stodden et al., 2008; Barnett et al., 2016). Similar challenges have been documented internationally, highlighting the need for effective interventions to support motor development worldwide (Stodden et al., 2008; Sheehan, 2018). There is strong evidence that physically active children are more likely to become physically active adults (Boreham & Riddoch, 2001; Ortega et al., 2008). Since PA participation is directly related to positive outcomes in all developmental domains, identifying factors in early childhood that could predict PA levels later in life may help health care professionals determine if an individual is at risk for health challenges associated with a sedentary lifestyle (Stodden et al., 2008; Robinson et al., 2015; Barnett et al., 2016).

Elementary PE can be a key setting for addressing OMS deficits, yet research indicates that PE programs often lack the quality and consistency required to develop these important OMS skills (McKenzie et al., 2001). According to the Canadian Health Measures Survey, only 13% of boys and 6% of girls aged 5 to 17 met the recommended 60 minutes of moderate-to-vigorous PA daily, with the rate for girls aged 12 to 17 dropping to just 3% (Canadian Institute of Child Health, 2012). Additionally, the 2024 ParticipACTION Report Card assigned a grade of D+ for overall PA among children and youth in Canada, highlighting persistent gaps in activity levels (ParticipACTION, 2024). Fundamental movement skills (FMS) and overall motor proficiency are positively associated with both general sport participation and involvement in organized physical activities that focus on developing sport specific skills in children (Ulrich, 1987; Raudsepp & Päll, 2006).

There should be no significant differences in OMS among pre-pubertal children until the onset of puberty, when muscle development and hormones begin to create differences between the genders (Sheehan, 2018). Before the milestone of accelerated adolescent growth, differences in physiology and OMS are minimal and changes only emerge because of adolescence (MacDonald et al., 2013; Sheehan, 2018). During the adolescent growth spurt, a child's motor proficiency may initially decrease causing disruptions in PE or daily activity routines. However, research suggests that when children become accustomed to their growing bodies, they regain previously developed OMS and apply them in sport and recreational pursuits (Sheehan & Lienhard, 2019). OMS are also associated with improved social behaviors and emotional regulation (MacDonald et al., 2016). These skills form the basis for many activities that encourage cooperation, self-control, and peer interaction, which can help children in fostering appropriate classroom behaviours and academic success (Pagani & Messier, 2012). Furthermore, the development of OMS is linked to cognitive processes and executive function (MacDonald et al., 2013). Children who develop stronger motor skills are better equipped to regulate their emotions and have a stronger attention span, which are important for navigating complex social situations and academic environments (MacDonald et al., 2013). Learning these skills has also been shown to boost self-competence and confidence, affecting how children perceive their abilities in different situations (Westendorp et al., 2014). Understanding how Canadian children's motor skills compare to established standards can help educators and policymakers create more effective PA programs that meet the specific needs of children across the country (Sheehan, 2018).

Warm-ups are designed to elevate body temperature, enhance neuromuscular activation, and prepare individuals mentally for physical exertion, thereby optimizing subsequent performance and reducing the risk of injury (Afonso et al., 2023; Fradkin et al., 2010). In school settings, brief, developmentally appropriate warm-up sessions have been shown to improve agility, coordination, and cardiorespiratory fitness, as well as to enhance attention, engagement and positive attitudes toward PA (Reis et al., 2024; Sople & Wilcox, 2024). Beyond physiological and cognitive benefits, warm-ups represent a practical and scalable means of integrating targeted skill development into existing PE structures. Embedding OMS activities within a short, daily warm-up provides students with consistent opportunities to practice FMS in a time-efficient format, addressing the limited motor-skill emphasis often found in PE curricula (McKenzie et al., 2001). These findings highlight the value of warm-ups not only as preparatory routines but as intentional interventions supporting both immediate performance and long-term engagement in PA.

Building on this rationale, the present study sought to evaluate the impact of a structured, six-week OMS warm-up on the motor proficiency of Grade 4 students in Alberta. We hypothesized that participation in this targeted warm-up would produce significant improvements in object manipulation performance across three standardized assessments, and that the gender gap in motor proficiency would narrow following the intervention.

Functional Motor Proficiency

Functional motor proficiency often refers to movement of the body that is characterized by adequately connecting body segments and muscle function, and has been shown to minimize risk of injury (Cook et al., 2006a; Cook et al., 2006b). It typically encompasses postural control, stability, flexibility, neuromuscular coordination, and balance. Fluid movement is an important building block in lifelong engagement and potentially injury-free engagement in organized sport (O'Brien et al., 2021). It has also been theorized as a precursor for higher-order and more complex forms of artistic and athletic movement (Duncan et al., 2013). Furthermore, adequate motor proficiency has shown positive associations with reading and writing among children and adolescents (Macdonald et al., 2018).

Building on this, the concept of physical literacy (PL) extends beyond motor proficiency to include self-motivation, confidence, and lifelong engagement in PA. Internationally, PL has formally been defined as the confidence, knowledge, physical competence and recognition of the importance of being physically active (Gabbard, 2018). Research has clearly shown that PA participation is influenced by movement skill, physical fitness and self-perceived motor skill competence (Stodden et al., 2008). Children, especially older adolescents, who are not competent in functional motor proficiency are less likely to be active adults later in life (Bouffard, et al., 1996; Lloyd et al., 2014; Lubans et al., 2010).

Object Manipulation Skills

This study builds on earlier research involving older Canadian children in middle school. Between 2012-2015, the OMS of 550 grade five and six students were assessed. Results from this study, coupled with other evidence-based literature, demonstrated that pre-adolescent girls were falling behind when it comes to developing OMS (Sheehan, 2018; Sheehan & Lienhard, 2019).

Existing research consistently shows that boys are traditionally more proficient in OMS and that this disparity may contribute to reduced participation and confidence as girls age (Barnett et al., 2010; Berkeley et al., 2001; Butterfield et al., 2012; Sheehan et al., 2020). Many interventions have focused specifically on identifying the OMS gap in boys and girls; however, there remains a notable lack of research on PE programming and how it relates to OMS development. In addition to a shortage of specific resources for girls, no studies have explored how boys and girls respond differently, or respond similarly to the same PE intervention. Investigating outcomes for both groups is essential to designing inclusive, developmentally appropriate programming that meets the needs of all children and promotes equitable access to PL development.

Based on the current body of knowledge, evidence supporting a customized curriculum intervention designed to increase OMS is missing from the literature. There also appears to be very little research that measures the effectiveness of an intentionally designed OMS warm-up program intervention as it relates to functional motor performance. This study seeks to fill this void by investigating the impact of a daily OMS elementary school PE warm-up in fourth-grade students.

Methodology

This study employed a single-group pre–post quasi-experimental design to examine changes in OMS and functional motor proficiency among Grade 4 students following a structured daily warm-up intervention. No control or comparison group was included, and a within-subjects design assessed changes in participants over time, and a between-subject design compared performance between girls and boys. The warm-up program was intentionally designed by an experienced elementary PE specialist teacher, and was grounded in self-determination theory (Deci & Ryan, 2000), intended to support autonomy, competence, and personal relatedness during PA. The warm-up routine was delivered independently of the concurrent PE instructional unit to maintain clear pedagogical and temporal separation between the intervention and standard curriculum activities. While the regular PE curriculum emphasized multi-skill games, locomotor activities, and sport-based learning outcomes, the warm-up sessions focused exclusively on OMS through structured, developmentally appropriate exercises such as throwing, catching, striking, and kicking. Each warm-up was conducted immediately prior to the scheduled PE lesson, lasted approximately ten minutes, and did not overlap in content, objectives, or assessment criteria with the broader PE program. This deliberate instructional differentiation and consistent scheduling helped to isolate the specific effects of the OMS warm-up from concurrent instruction, thereby strengthening the internal validity of the design while maintaining feasibility within the school's daily timetable.

A warm-up format was selected over a full instructional unit to maximize feasibility, time efficiency, and sustainability within the constraints of daily school programming. Brief, structured sessions can be implemented consistently across classes with minimal disruption to existing PE curricula, thereby enhancing the ecological validity of the intervention. Short-duration activities also allow for high-frequency exposure and repeated practice of fundamental skills within a manageable timeframe, supporting OMS learning without imposing additional instructional demands on educators. This design provides a scalable model for integrating targeted skill development into routine PE practice, ensuring equitable access to quality movement experiences for all students.

Participants

Participants were recruited from a single publicly funded elementary school in Alberta, Canada, through collaboration with the school's PE specialist teacher. All Grade 4 students enrolled in PE were invited to participate via informational letters and consent packages distributed to parents and guardians. The package included details about study objectives, procedures, and confidentiality assurances. Recruitment was conducted one week prior to data collection, and participation was entirely voluntary. Signed parental consent and verbal child assent were obtained for all participants prior to testing.

A total of 48 students (N = 48; 28 boys, 20 girls), aged 9 to10 years, provided consent and completed both pre- and post-intervention assessments. No participants withdrew or were excluded during the six-week intervention. All students were able to complete the physical assessments and participate in the full program.

The school population represented a typical suburban demographic for the region, with students of diverse backgrounds and access to standard PE programming delivered by a certified specialist. Inclusion criteria required that students were enrolled in Grade 4 PE, medically cleared for regular PA, and available for all phases of data collection. No exclusion criteria were applied beyond the ability to safely participate in moderate-intensity PE activities. Ethics approval for this study was granted by the Human Research Ethics Board at Mount Royal University.

Instruments

The Bruininks-Oseretsky Test of Motor Proficiency-second edition (BOT-2)

The Upper Limb Coordination subtest from the BOT-2 was used to evaluate quantitative, product-oriented motor proficiency related to OMS. The subtest included tasks such as catching and throwing a ball, and dribbling with one or both hands. Each task was scored according to the standardized scoring procedures, and raw scores were converted to point values for analysis. The BOT-2 has been widely validated for children aged 4-21 and is commonly used in educational and clinical settings (Deitz et al., 2007). The Upper Limb Coordination subtest involved seven tasks designed to assess participants' ability to manipulation objects using their hands and these tasks include (Bruininks & Bruininks, 2005):

1. Catching a ball with both hands after it is dropped
2. Catching a ball with both hands from ten feet
3. Dropping and catching a ball with one hand
4. Catching a ball with one hand from a ten-foot distance
5. Dribbling a ball with one hand
6. Alternating between hands while dribbling a ball
7. Throwing a ball at a target

The Test of Gross Motor Development-version 3 (TGMD-3)

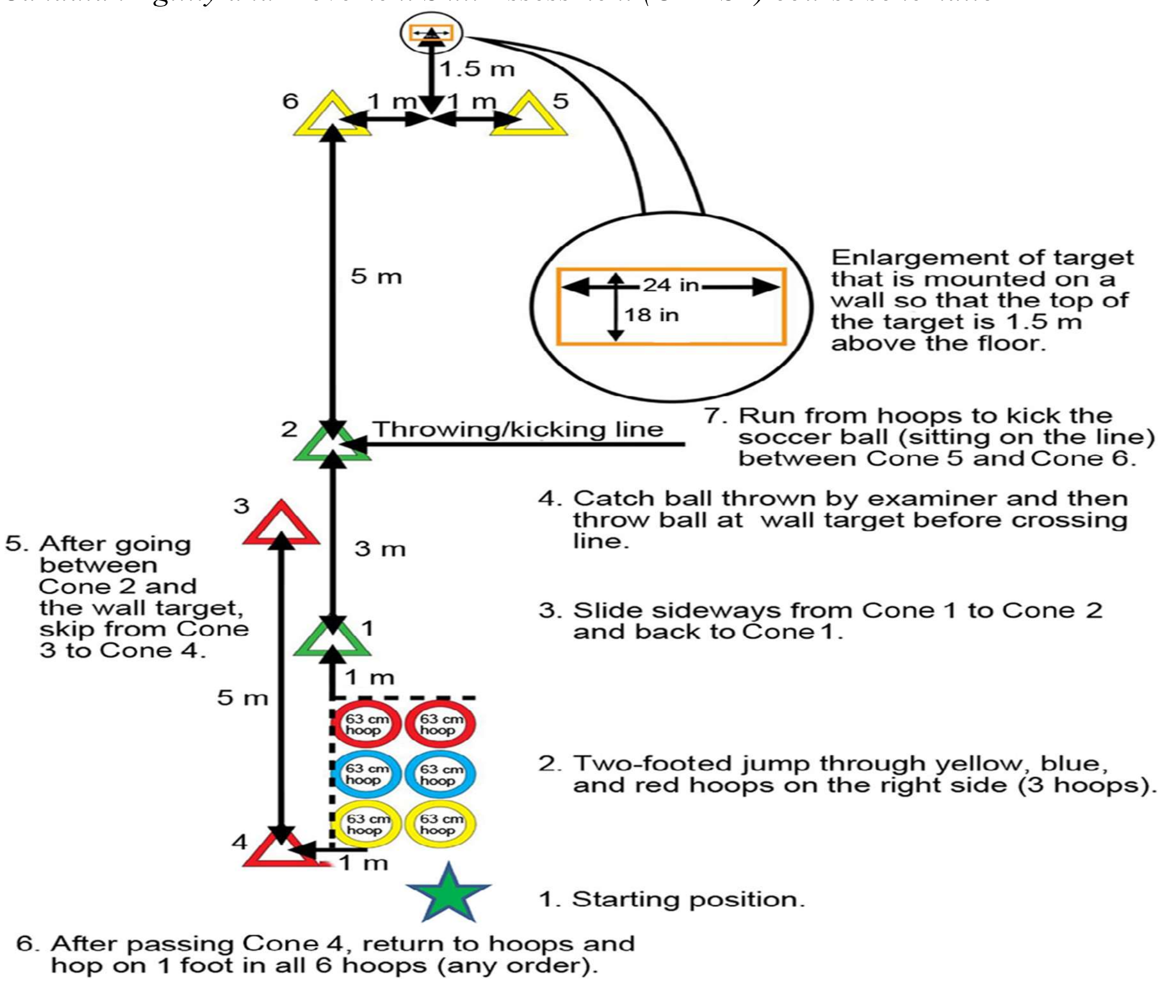
The TGMD-3 evaluates a total of thirteen FMS, split into two categories: locomotor skills and ball skills (Ulrich, 2013). Only the ball skills subtest was used for this study and included qualitative process-oriented assessments of kicking, striking (one and two handed), dribbling, catching, overhand throwing, and underhand throwing. After a demonstration by the Research Assistant (RA) and one practice attempt, each participant completed two formal trials of each item. Each trial was scored using a standardized procedure based on the TGMD-3 technique criteria. A review of the TGMD-3 validation literature confirmed that this tool demonstrated good to excellent inter-rater and intra-rater reliability and moderate to excellent test-retest reliability, thus supporting its use as a robust tool for assessing OMS in children (Zhu et al., 2025).

Canadian Agility and Movement Skill Assessment (CAMSA)

The CAMSA was used to assess students' overall movement competence by evaluating both the quality and speed of their skill execution. The assessment involved a 20-meter circuit with seven tasks performed in sequence: jumping, side-stepping, skipping, hopping, kicking, throwing, and catching (Figure 1). These tasks simulated real-life PA demands. Participants were asked to complete the assessment as quickly and accurately as possible, with both speed and movement quality being key measures. Each participant performed two timed and scored trials, after the RA demonstrated the tasks twice: first slowly, with an explanation of each skill, and then more quickly, emphasizing the accuracy and speed required. A "go" command signaled the start of timing, and verbal cues were provided before each skill. No feedback was given regarding task performance. Two trained RA's were present during the assessment: one provided cues and assisted with the catch, throw, and kick, while the other assessed skill quality. The CAMSA is a subsection of the Canadian Assessment of PL (CAPL) and is a validated and reliable tool for assessing motor proficiency in children aged 8 to 12 (Longmuir et al., 2015).

Figure 1

Canadian Agility and Movement Skill Assessment (CAMSA) course schematic



Procedures

All participants completed baseline testing prior to week 1, and a post-intervention evaluation after week 6. Data collection was conducted during school hours in the gymnasium or designated PE space by trained RA's to ensure consistency and accuracy. Prior to data collection, all RA's completed training sessions that included joint scoring of pilot participants to ensure procedural consistency and adherence to test manuals. Although inter-rater reliability was not formally calculated for this sample, standardized training and supervision were used to minimize variability between raters. Each assessment session lasted approximately 20 minutes per child, with all participants completing the tasks in the same order each time. This structured testing protocol allowed for the comparison of results and a clear understanding of any changes in participants' OMS and competence.

Intervention

The intervention took place over six consecutive weeks and was implemented daily as a structured warm-up routine at the beginning of each PE class. Each warm-up session lasted approximately 10 minutes and was purposely designed to emphasize OMS through focused, progressive, and engaging activities. Each warm-up served as both an OMS practice opportunity and a chance to foster motivation through positive social interaction and the promotion of student autonomy. A consistent weekly structure ensured a well-rounded approach to skill development, with each week targeting different components of OMS. Table 1 provides an overview of the daily warm-up intervention, including the weekly focus, example activities, required equipment, and key pedagogical features.

Each session was designed to promote autonomy by allowing students to choose equipment and select their own preferred activity every Friday. Relatedness was fostered through structured partner and small-group activities that emphasized teamwork and support. To build competence, students had ample opportunities for repeated practice, and video feedback using iPads allowed them to self-monitor and visually track their progress. The PE environment was enhanced with upbeat music, colorful equipment, and consistent routines to create a warm and inclusive atmosphere. The PE teacher provided ongoing encouragement and instructional cues. All students, regardless of skill level, were encouraged to participate to the best of their ability. Boys and girls participated in the same warm-up routines, and no instructional differentiation by gender was implemented during the program. Intervention fidelity was systematically monitored to ensure consistent delivery across all sessions. The implementing PE teacher completed daily adherence logs documenting session duration, completion of planned activities, and any modifications made to accommodate class circumstances. These records were reviewed weekly by the research team to confirm that the warm-up routine aligned with the prescribed structure and pedagogical intent. High adherence was maintained throughout the six-week program, with all sessions delivered as scheduled, ensuring fidelity to the intended intervention design.

Table 1

Overview of the Daily Object Manipulation Skills Physical Education Warm-up Intervention

Time	Focus	Daily Warm-up Activities	Equipment Examples	Key Pedagogical Features
Week 1	Setting the stage for success	- Introduction to OMS and FMS - Team building activities (e.g., create team names, chants) - OMS team activities (e.g., Adventure challenge, circuits)	- Team-coloured spots/markers - Gator balls - Omnikin Balls - Circus arts equipment	- Introduction to fundamental movement concepts - Team building and relatedness - Gamified skill development
Week 2 - 6	Daily OMS and FMS Skills			
Monday	Throwing and catching	- Partner and team throwing/catching challenges - Circus arts (juggling balls, devil sticks, plate spinning) - Spikeball rebounding circuits - Omnikin ball team throws	- Gator balls - Juggling balls - Tennis balls - Omnikin balls - Spikeball nets	- Hand-eye coordination - Passing accuracy - Movement while manipulating objects
Tuesday	Hand dribbling	- Basketball dribbling in open space - Tennis ball dribbling partner circuits - Perimeter movement challenges (run, skip, hop while dribbling)	- Basketballs - Tennis balls	- Ball control - Switching hands - Movement under control
Wednesday	Striking	- Tennis racquet pat-downs and pop-ups - Table tennis wall strikes - Badminton rallies - Mini-striking stations	- Tennis racquets - Table tennis paddles - Badminton racquets - Birdies - Mini-nets	- Precision and timing - Striking consistency across implements
Thursday	Foot dribbling and kicking	- Soccer ball dribbling circuits - Soccer capture game - Hacky Sack footwork challenges	- Soccer balls - Hacky Sack footbags - Mini soccer nets	- Foot-eye coordination - Lower body ball control
Friday	Student choice	- Free choice object manipulation activities - Must integrate OMS and FMS movement	- Full equipment access	- Student autonomy - Exploration - Creativity - Sustaining active movement

Note – OMS = Object Manipulation Skills; FMS = Fundamental Movement Skill

Data Analysis and Statistics

Data are presented as mean ± standard deviation (SD), unless otherwise specified. All statistical analyses were conducted using JASP v0.19.3 (JASP Team, 2025). Normality and homogeneity of variance were assessed using the Shapiro-Wilk test ($p > 0.05$) and Levene's test ($p > 0.05$), respectively. Descriptive statistics were calculated for age, height, weight, and BMI *z*-scores by gender. To evaluate within-group changes over time, paired-samples *t*-tests were conducted comparing pre- and post-test scores for each outcome measure: BOT-2 Upper Limb Coordination, TGMD-3 Ball Skills, and CAMSA total score. Independent-samples *t*-tests were used to compare boys and girls at baseline and post-test. To examine the combined influence of time (pre-test, post-test) and gender (boys, girls) on object manipulation outcomes, separate 2 × 2 mixed-design analyses of variance (ANOVA)s were conducted for each dependent variable (BOT-2, TGMD-3, and CAMSA). Partial eta squared (η^2_p) was reported as a measure of effect size for ANOVA results.

Age and BMI were not included as covariates because the sample comprised a single grade level (Grade 4) with a narrow age range (9–10 years) and homogeneous BMI distribution (SD = 0.8). These characteristics minimized the likelihood of confounding effects on motor performance. Baseline skill level was not statistically controlled for, as pre-test values were used to compute change scores and interpret within-participant improvements. Effect sizes were interpreted according to established benchmarks. For *t*-tests, Cohen's *d* values of ≥ 0.20, ≥ 0.50, and ≥ 0.80 were considered small, medium, and large effects, respectively. For mixed-design ANOVAs, partial eta squared (η^2_p) values of ≥ 0.01, ≥ 0.06, and ≥ 0.14 were interpreted as small, medium, and large effects, respectively (Cohen, 1988). The *a priori* level of statistical significance was set at $p < 0.05$.

Results

A total of 48 Grade 4 students (N = 48) participated in the study, including 28 boys (n = 28) and 20 girls (n = 20). A single group pre-post test design without a control group was employed, with assessments conducted six weeks apart to evaluate OMS. Participant characteristics are presented in Table 2.

Table 2

Descriptive Data of Participants at Baseline (Pre-Test)

Measure	Combined (N = 48)	Boys (n =28)	Girls (n = 20)	Boys vs. Girls Two-Sample T-Test (*p* value)
Age (years)	9.3 (0.5)	9.3 (0.4)	9.3 (0.5)	.988
Height (cm)	137.2 (4.9)	137.5 (5.4)	136.7 (4.1)	.538
Weight (kg)	32.4 (5.0)	33.1 (5.3)	31.4 (4.3)	.254
BMI Z-Score	0.1 (0.8)	0.2 (0.8)	-0.1 (0.8)	.154

Note – Bracketed values represent ± standard deviation; *cm = centimeters; kg = kilograms; BMI = Body Mass Index*

BOT-2 Upper limb coordination

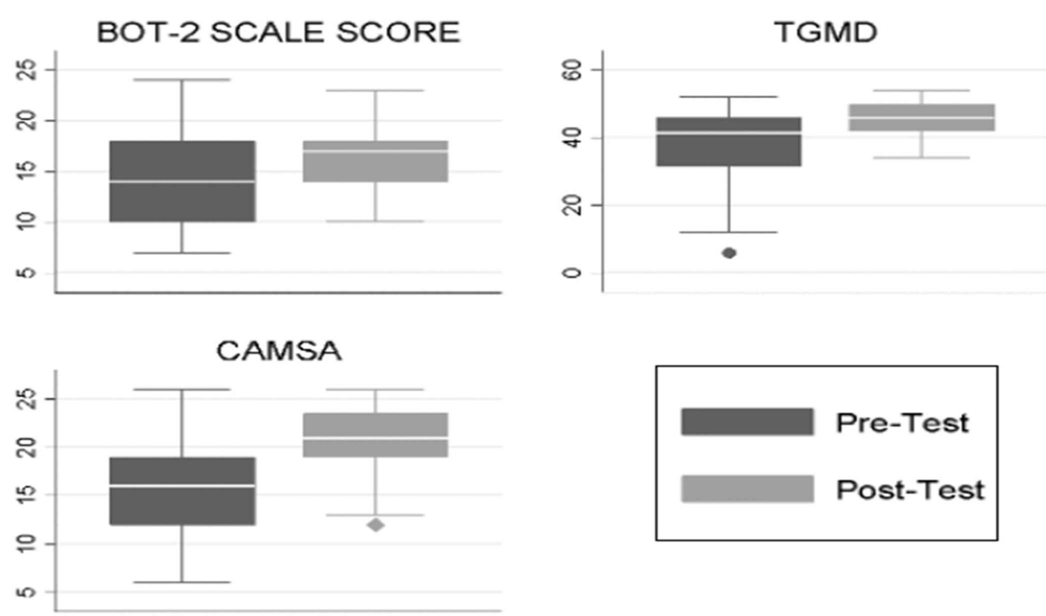
Participants demonstrated significant improvement from pre-test to post-test on the BOT-2 Upper Limb Coordination subscale (mean difference [MD] = 2.23, 95% confidence interval [CI] [0.80, 3.66], $t(47) = 3.13$, $p = .003$, $d = 0.45$; Figure 2, Table 3). Within-group analyses showed significant gains for both girls (MD = 2.20, 95% CI [0.02, 4.38], $t(19) = 2.12$, $p = .048$, $d = 0.47$) and boys (MD = 2.25, 95% CI [0.23, 4.27], $t(27) = 2.29$, $p = .030$, $d = 0.43$). No significant differences were observed between gender at either the pre-test (MD = 0.56, 95% CI [-2.01, 3.21], $t(46) = 0.43$, $p = .669$, $d = 0.13$) or post-test (MD = 0.61, 95% CI [-1.51, 2.74], $t(46) = 0.58$, $p = .563$, $d = 0.17$) assessments (Table 4). A mixed-design ANOVA revealed a significant main effect of time ($F(1, 46) = 9.29$, $p = .004$, $\eta^2_p = .17$). The main effect of gender was not significant ($F(1, 46) = 0.39$, $p = .534$, $\eta^2_p = .01$), and the time × gender interaction was also non-significant ($F(1, 46) = 0.00$, $p = .973$, $\eta^2_p < .001$; Figure 3)

TGMD-3 (ball skills)

Participants showed significant improvement in TGMD-3 ball skills scores from pre-test to post-test (MD = 7.94, 95% CI [5.19, 10.69], $t(47) = 5.81$, $p < .001$, $d = 0.84$; Figure 2, Table 3). Both girls (MD = 11.05, 95% CI [5.61, 16.49], $t(19) = 4.25$, $p < .001$, $d = 0.95$) and boys (MD = 5.71, 95% CI [3.01, 8.42], $t(27) = 4.33$, $p < .001$, $d = 0.82$) improved significantly over time. Boys scored significantly higher than girls at both the pre-test (MD = 11.04, 95% CI [5.62, 16.45], $t(46) = 4.10$, $p < .001$, $d = 1.20$) and post-test (MD = 5.70, 95% CI [3.09, 8.31], $t(46) = 4.39$, $p < .001$, $d = 1.29$; Table 4). A mixed-design ANOVA revealed a significant main effect of time ($F(1, 46) = 38.85$, $p < .001$, $\eta^2_p = .46$) and gender ($F(1, 46) = 26.40$, $p < .001$, $\eta^2_p = .37$). The time × gender interaction approached significance ($F(1, 46) = 3.94$, $p = .053$, $\eta^2_p = .08$; Figure 3)

Figure 2

Pre-Test and Post-Test Object Manipulative Scores Across CAMSA, TGMD-3 Ball Skills, and BOT-2 Upper Limb Coordination



Note - BOT-2 = Bruininks-Oseretsky Test of Motor Proficiency - Second Edition, TGMD-3 = Test of Gross Motor Development - Version 3, CAMSA = Canadian Agility and Movement Skill Assessment

CAMSA

Significant improvements were observed for CAMSA scores from pre-test to post-test (MD = 5.33, 95% CI [4.16, 6.51], $t(47) = 9.16$, $p < .001$, $d = 1.32$; Figure 2, Table 3). Within-group analyses indicated significant increases for both girls (MD = 6.65, 95% CI [4.96, 8.34], $t(19) = 8.22$, $p < .001$, $d = 1.84$) and boys (MD = 4.39, 95% CI [2.80, 5.99] $t(27) = 5.65$, $p < .001$, $d = 1.07$). Boys outperformed girls at both time points, with a significant difference at pre-test (MD = 4.68, 95% CI [2.36, 7.00], $t(46) = 4.07$, $p < .001$, $d = 1.19$) and post-test (MD = 2.42, 95% CI [0.41, 4.43], $t(46) = 2.43$, $p = .019$, $d = 0.71$; Table 4). A mixed-design ANOVA showed a significant main effect of time, ($F(1, 46) = 92.80$, $p < .001$, $\eta^2_p = .67$) and gender, ($F(1, 46) = 15.15$, $p < .001$, $\eta^2_p = .25$). The time × gender interaction approached significance ($F(1, 46) = 3.88$, $p = .055$, $\eta^2_p = .08$; Figure 3).

Table 3

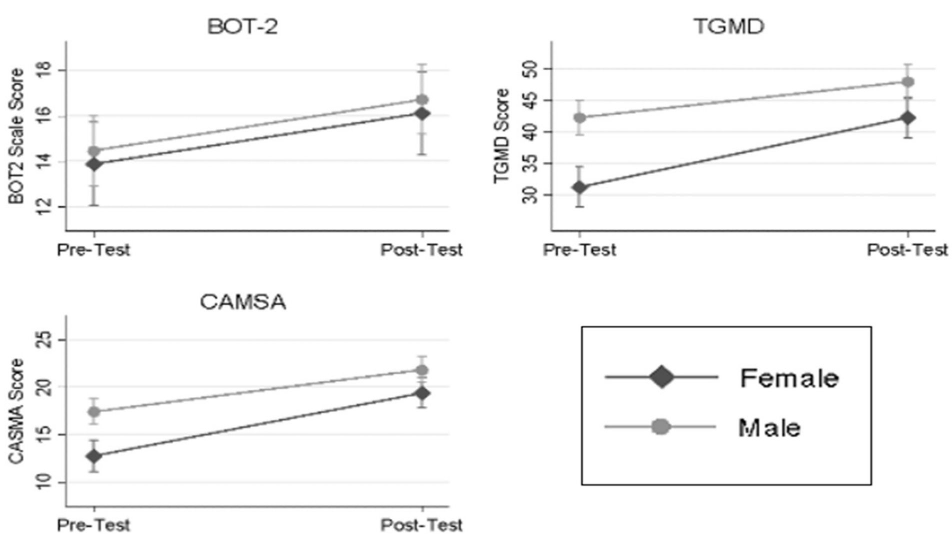
Pre-Test and Post-Test Scores for Object Manipulative Skill Assessments

Assessment	Pre-Test Mean	Post-Test Mean	Paired T Test (*p* value)
BOT-2	14.23 (4.45)	16.46 (3.58)	.003
TGMD-3	37.69 (10.62)	45.63 (5.23)	< .001
CAMSA	15.48 (4.53)	20.81 (3.58)	< .001

Note - Bracketed values represent ± standard deviation, BOT-2 = Bruininks-Oseretsky Test of Motor Proficiency - Second Edition; TGMD-3 = Test of Gross Motor Development - Version ;, CAMSA = Canadian Agility and Movement Skill Assessment.

Figure 3

Pre-Test and Post-Test Scores by Gender for CAMSA, TGMD-3 Ball Skills, and BOT-2 Upper Limb Coordination



Note - Error bars represent 95% confidence intervals. BOT-2 = Bruininks-Oseretsky Test of Motor Proficiency - Second Edition; TGMD-3 = Test of Gross Motor Development - Version 3; CAMSA = Canadian Agility and Movement Skill Assessment.

Table 4
Pre-Test and Post-Test Gender Difference and Within-Gender Improvements Across Object Manipulative Skill Measures

Assessment	Pre-test	Post-test	Within Group Mean Change (95% CI)	Within Group (*p* value)
BOT-2				
Girls (n = 20)	13.90 (4.77)	16.10 (3.08)	2.20 (0.02, 4.38)	.048
Boys (n = 28)	14.46 (4.27)	16.71 (3.93)	2.25 (0.23, 4.27)	.030
Group Difference (95% CI)	0.56 (-2.01, 3.21)	0.61 (-1.51, 2.74)		
p value	.669	.563		
TGMD				
Girls (n = 20)	31.25 (11.89)	42.30 (5.32)	11.05 (5.61,	< .001
Boys (n = 28)	42.29 (6.66)	48.00 (3.68)	16.49) 5.71 (3.01, 8.42)	< .001
Group Difference (95% CI)	11.04 (5.62, 16.45)	5.70 (3.09, 8.31)		
p value	< .001	< .001		
CAMSA				
Girls (n = 20)	12.75 (3.39)	19.40 (3.67)	6.65 (4.96, 8.34)	< .001
Boys (n = 28)	17.43 (4.27)	21.82 (3.22)	4.39 (2.80, 5.99)	< .001
Group Difference (95% CI)	4.68 (2.36, 7.00)	2.42 (0.41, 4.43)		
p value	< .001	.019		

Note - Bracketed values represent ± standard deviation*, BOT-2 = Bruininks-Oseretsky Test of Motor Proficiency - Second Edition, TGMD-3 = Test of Gross Motor Development - Version 3, CAMSA = Canadian Agility and Movement Skill Assessment, CI = Confidence Interval*

Discussion

The purpose of this study was to evaluate the effectiveness of a six-week warm-up intervention designed to improve OMS among fourth grade Canadian girls and boys. Findings indicate that a structured, daily OMS warm-up routine can significantly enhance motor proficiency in elementary-aged children. The observed improvements in motor proficiency may reflect the interaction of practice frequency, motivation, and social engagement fostered by the daily warm-up structure. Repeated exposure to object manipulation tasks in a consistent, low-pressure environment likely enhanced neuromuscular coordination and refined technique through incremental adaptation and feedback. Grounded in the principles of Self-Determination Theory (Deci & Ryan, 2000), the warm-up promoted autonomy, competence, and relatedness, psychological conditions that support intrinsic motivation and sustained effort. Opportunities for self-directed choice (e.g., equipment selection on Fridays), peer collaboration, and positive reinforcement may have created a sense of ownership and enjoyment, further strengthening engagement. The socially interactive design of the sessions encouraged cooperation and peer support, elements that contribute to both motor learning and confidence. However, in the absence of a control group, it is important to acknowledge that these gains cannot be attributed solely to the warm-up, as maturation, other PE activities, or outside-of-school experiences may have contributed.

Statistically significant improvements were observed across all three assessment tools, the BOT-2, TGMD-3, and CAMSA, demonstrating the value of embedding intentional skill development within existing PE programming. The intervention was designed to cultivate autonomy, competence, and relatedness, three key factors known to support sustained engagement in PA (Deci & Ryan, 2000). Students exercised autonomy through meaningful choices such as selecting equipment, choosing partners, or adjusting task difficulty to match their abilities. Additionally, each Friday featured a structured student-choice session in which learners selected their own equipment and applied OMS in self-designed activities. Competence was fostered through scaffolded skill progression and immediate feedback, enabling students to experience measurable improvement and confidence in their performance. Relatedness emerged through partner- and team-based activities that emphasized cooperation, peer encouragement, and shared success, contributing to a supportive and inclusive class climate. Together, these elements likely enhanced intrinsic motivation, engagement, and persistence throughout the six-week program.

Notably, both girls and boys improved in upper limb coordination as measured by the BOT-2, with no statistically significant gender differences observed at either pre- or post-test. This may be attributed to the product-oriented nature of the BOT-2, which emphasizes task outcomes (e.g., ball control and target accuracy) rather than technique. The daily practice and repetition inherent in the warm-up may have helped all students, regardless of prior experience, achieve these measurable outcomes. Social engagement during the warm-up, such as collaborative drills and peer encouragement, may have further reinforced participation and effort. These findings suggest that when students are provided with equitable, structured, and supportive practice opportunities, gender-based differences in specific motor tasks can be minimized (Okely et al., 2001; Robinson & Goodway, 2009).

In contrast, results from the TGMD-3 ball skills subtest revealed gender disparities, with boys outperforming girls at both assessment points. This aligns with existing literature suggesting that boys are often introduced to sport and ball-related play at an earlier age, contributing to a higher baseline proficiency (Barnett et al., 2010; Butterfield et al., 2012). Addressing these disparities requires both targeted interventions and broader systemic changes. One promising approach involves gender-responsive programming, such as the girls-only intervention evaluated by Sheehan et al. (2020), which led to significant improvements in girls' ball skills. Similarly, Pratt et al. (2008) emphasized the importance of early, skill-focused opportunities for girls to build motor competence and confidence. Future interventions could prioritize equitable access to sport by embedding inclusive PL programming within the school curriculum, offering girls-only PA spaces, and expanding community-based programs that engage girls from a young age. Making daily PE mandatory, with an emphasis on varied and developmentally appropriate activities, may also help to level the playing field (Robinson et al., 2017). Additionally, designing activities that appeal to diverse interests, beyond traditional sport, can encourage greater participation and skill development among under-represented groups (Gabbard, 2018; Okely et al., 2004). The structured warm-up focused on gradual skill mastery, which likely helped reduce the gender gap in CAMSA scores, demonstrating how thoughtful and inclusive practice can promote equity in OMS development. The intervention appeared to benefit girls, who demonstrated a greater mean improvement in ball skills compared to boys. This finding was supported by the near-significant time × gender interactions observed for both the TGMD-3 and CAMSA, which suggest a trend toward greater relative improvement among girls. Although these interactions did not reach conventional levels of significance, the consistent direction of change across both assessments indicates that girls may have derived slightly greater benefit from the warm-up. This pattern is meaningful given that girls began with a significantly lower baseline object manipulation proficiency, and it highlights the capacity of inclusive, skill-specific programming to narrow existing gender gaps. The post-intervention reduction in gender differences on CAMSA, combined with the large overall improvements observed, reinforces the value of brief, structured, and equitable warm-up interventions in supporting students who may have had fewer prior opportunities to develop these competencies. These trends underscore that even modest, daily exposure to targeted OMS activities can meaningfully contribute to improving motor competence among under-represented groups, promoting both equity and engagement in physical education.

These findings support prior research identifying OMS as a foundational element of PL, and a strong predictor of sustained PA engagement across the lifespan (Sheehan et al., 2020; Stodden et al., 2008). The observed narrowing of gender disparities suggests that inclusive, targeted programming can help address OMS gaps that often emerge in early childhood and widen with age (Barnett et al., 2010; MacDonald et al., 2016). In this study, gender-neutral activities and consistent exposure to object manipulation tasks provided equitable opportunities for practice and success, which may have contributed to the reduction in performance differences between boys and girls. While boys consistently scored higher overall, the substantial improvements observed among girls highlight the potential for school-based interventions to support both competence and confidence in motor development (Lubans et al., 2010; Westendorp et al., 2014). By offering structured, developmentally appropriate practice opportunities, the warm-up may also reinforce motor learning through repetition and feedback, strengthening both skill and self-efficacy. Enhanced motivation and social engagement during the warm-up may have amplified these effects, helping students maintain effort and persistence throughout the intervention. Since OMS proficiency is linked to broader cognitive, emotional, and social development, enhancing these skills may offer benefits that extend beyond physical health (MacDonald et al., 2013). Structured warm-ups provide repeated, scaffolded opportunities for skill development while maintaining engagement, which may explain why such programs are effective in promoting both competence and confidence (Love et al., 2017; Robinson & Goodway, 2009). The large effect sizes observed across all assessments indicate that even brief, daily exposure to OMS-specific activities can yield meaningful improvements in children's motor competence.

A key strength of this study was the involvement of an expert in the field of elementary PE (BKin, BEd) who tailored the intervention specifically to the needs of the students. This ensured that the activities were age-appropriate, engaging, and aligned with best practices in OMS development. Additionally, the participants in this study were particularly receptive to the intervention, likely because the warm-up was designed to be enjoyable, achievable, and progressive, reinforcing motivation and engagement in PA. This highlights the value of a structured program in motivating children to engage with and improve their physical abilities.

While the intervention demonstrated positive outcomes, there were some limitations to consider. One key limitation was the relatively small sample size, which may limit the generalizability of the findings. Future studies should consider using larger, more diverse samples to assess the broader applicability of the intervention across different school settings and populations. Although data were collected by trained research assistants following standardized procedures, inter-rater reliability was not formally assessed, which may introduce minor measurement variability. Additionally, the short duration of the intervention (six weeks) may not have been sufficient to capture long-term changes in motor proficiency.

Longer interventions could also clarify whether repeated warm-up practice continues to drive improvements over time and contributes to sustained engagement in PA. The single-group pre-post design, without a control group, limits causal inference, as improvements cannot be attributed solely to the warm-up intervention. Fidelity of implementation is another potential constraint; although the intervention was delivered by an expert in elementary PE, variations in execution across sessions or differences in student engagement could have influenced outcomes. Analytical constraints also exist, including reliance on aggregate scores and limited ability to account for individual differences in baseline skill, maturation, or outside-of-school PA, which may have contributed to the observed improvements.

Future research could benefit from incorporating the Perceived Competence Motivation Scale (PCMS) or similar subjective assessments to gain deeper insight into students' self-perception of their motor skills and their motivation to engage in PA. Subjective assessments such as these can be crucial for building self-efficacy among children, as they provide valuable feedback on how children perceive their own capabilities, which can influence their long-term participation in physical activities (Deci & Ryan, 2000). Incorporating such measures alongside objective skill assessments would allow researchers to better understand how interventions like warm-ups affect both ability and confidence, providing a more comprehensive picture of their impact. Such tools could help identify potential areas for improvement and allow for more personalized intervention strategies. Integrating qualitative data from students, teachers, and parents could shed light on the emotional and social factors that contribute to skill development and engagement in PE. Additionally, future studies could compare the effects of a warm-up only intervention to full-unit instruction in PE, examining whether similar or greater gains in OMS occur when warm-ups are embedded within broader skill instruction. Longitudinal research could also investigate the long-term retention of motor skills and sustained engagement in PA, helping to determine the lasting impact of brief, structured interventions on children's PL.

Conclusion

The findings of this study demonstrate that embedding structured OMS opportunities into daily PE programming can produce meaningful improvements in motor proficiency among elementary school children. Beyond short-term performance gains, the intervention contributed to a narrowing of gender disparities in key motor domains, suggesting that early, inclusive support can promote more equitable physical development. These results carry important implications for educators, policymakers, and curriculum developers seeking to foster PL in a diverse student population. By providing all children, regardless of gender, with consistent, developmentally appropriate opportunities to build foundational movement skills, schools can help lay the groundwork for lifelong engagement in PA. The potential impact of OMS development extends beyond physical health, and can influence children's confidence, social relationships, and academic readiness. Moving forward, sustained attention to inclusive OMS programming in the early school years will be essential to addressing persistent gender gaps in participation, competence, and health outcomes. The brevity and scalability of a daily OMS warm-up make it a feasible strategy for embedding motor-skill development in routine PE practice; however, controlled trials are needed to isolate its unique contribution.

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