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The Effect of Pedagogical Approach on Physical Activity of Girls During Physical Education

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ABSTRACT

Purpose: Technical approaches (TAs) such as Direct Instruction are commonly utilized when teaching games in Physical Education (PE) classes, but game-based approaches (GBAs) such as Game Sense (GS) have gained greater interest over the past 30 years. However, little is known about which approach promotes more physical activity (PA). The aim of this study was to compare the PA of girls during single-gender PE classes in an invasion games unit utilizing either a GS approach or a TA. **Methods:** Two upper primary school PE classes were taught invasion games using a GS approach and two classes were taught using a TA. During each of the 7 lessons students wore a wearable GPS sensor (SPT2, Sport Performance Tracking, Australia) which measured total distance, distance in each speed zone, top speed and 3D load. **Results:** The GS group traveled a greater distance than the TA group (+203 m, $p < .001$). This result was explained mostly by a greater distance covered in zone 2 speeds (0.6–1.7 m/s). The 3D load was also significantly higher in the GS group, but there were no group differences in top speed. **Conclusions:** Findings suggested that a GS thematic invasion unit was more effective in promoting PA levels in all-girl primary PE classes than a traditional sport-based invasion unit.

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Game sense; movement; school; traditional approach; wearable technology

Teaching games in physical education using different approaches

Numerous pedagogies specific to Physical Education (PE) have been defined and used depending on the intended teacher or student outcomes (Gurvitch & Metzler, 2013). When teaching games and sports in PE, two methods that teachers commonly use can be broadly classified as either a game-based approach (GBA) (Teaching Games for Understanding Special Interest Group [TGfU SIG], 2021) or a technical (traditional) approach (TA) (Metzler & Colquitt, 2021). GBAs are characterized as learner-centered and utilize modified games as the central learning activity (TGfU SIG, 2021), with teachers changing or modifying elements of the game and questioning the learners to challenge their thinking in developing solutions to game problems (Light et al., 2014; Stolz & Pill, 2013). In contrast, TAs are teacher-centered and utilize a technical mastery approach with students repetitively practicing isolated sport techniques prior to applying these in a game situation, whilst being provided with direct and explicit instruction and feedback (Breed & Spittle, 2021). Such traditional models are currently the most utilized approaches in PE, but more contemporary curricula propose that PE games units should be non-sport specific, or thematic (i.e., invasion, striking and fielding, net and wall, target games), to address a wider range of student skills and outcomes that are more transferrable across multiple domains (Mitchell et al., 2020; Roca & Williams, 2017). Invasion games are the most common form of games in PE and involve an attacking team that aims to keep possession of the ball, create space and score a goal, with a defending team aiming to prevent a score (e.g., netball, basketball, soccer) (Breed et al., 2024).

Many studies have compared a single sport unit using a GBA and TA with the majority investigating basketball (Güneş & Yılmaz, 2019; López et al., 2016) and soccer (J. García-Ceberino et al., 2020a; Gouveia et al., 2019; Smith et al., 2015) and focusing predominately on measuring the skill development of students. Much of the development of GBAs in PE have been attributed to the "Teaching Games for Understanding" (TGfU) model first proposed in 1982 (Bunker & Thorpe, 1982). Whilst there are some subtle differences between various GBAs, they share common elements related to cognitive, constructivist, non-linear pedagogy and situated learning theories, with modified games as the central context through which learners develop their skills with problem-solving and responding to questioning (Metzler & Colquitt, 2021). One such approach is a Game Sense (GS) model recently developed for PE teachers (Breed & Spittle, 2021) designed with both a thematic content approach and a pedagogical framework based on key GBA features. The games are classified and presented in categories or themes such as invasion, striking and fielding, and net and wall games (Mitchell et al., 2020). In the Breed and Spittle (2021) GS model, a specific sport unit is not taught, rather a progressive sequence of modified games that relate to tactical similarities within a group of sports (e.g., invasion games).

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Units of work for teaching games within PE have traditionally been developed primarily with a skill-focus, and sometimes affective outcomes, as the central organizing factor, with PA levels often not considered as a primary outcome (Miller, 2015). Whilst there has been some research using targeted PA interventions to increase moderate-vigorous PA (MVPA) (Lonsdale et al., 2013), there is little research investigating the use of games for increasing student PA in PE. It is the intent of this current research to investigate if there is a difference in the amount of PA experienced by children participating in either a GS unit and TA unit that primarily had a skill and affective outcome focus within the context of the Australian curriculum.

Student outcomes from GBAs and TAs

Student outcomes are commonly classified into three main domains that can (and should) be developed through quality PE teaching in games and sport units: cognitive, affective and physical/motor (Rudd et al., 2020). It has been claimed that all these key domains must be addressed to facilitate engagement in physical activity throughout life (Bailey et al., 2009). The cognitive domain generally includes declarative (theoretical knowledge such as rules and goals of the game) and procedural (or contextual) knowledge (application of knowledge to actions) (J. García-Ceberino et al., 2020b). Several studies comparing a GBA with a TA using invasion sports have demonstrated similar improvements in both declarative knowledge and procedural knowledge (Güneş & Yılmaz, 2019; Olosová & Zapletalová, 2015) but some studies have shown GBAs to be more effective in improving students' procedural knowledge (López et al., 2016; Stephanou & Karamountzos, 2020) when measured using written or oral questions.

Affective outcomes can include many factors, such as motivation, perceived competence, friendships, and enjoyment (Koekoek & Knoppers, 2015; White et al., 2021), but this domain has been underrepresented with a need for further research (Barba-Martín et al., 2020; Harvey & Jarrett, 2014). Most of the research focus comparing outcomes of GBAs and TAs has been on student skill development, measuring technical skills using isolated skill testing (López et al., 2016; Miller et al., 2015) and tactical skills using a game performance assessment instrument (GPAI) (Chatzopoulos et al., 2006; Gouveia et al., 2019). A recent meta-analysis reported that GBAs significantly improved decision-making, but not skill execution, when compared to TAs, in a variety of PE and sport settings (Robles et al., 2020). Whilst previous research in PE has focussed predominately on measuring motor skill outcomes in a single sport (Miller, 2015; Morales-Belando et al., 2021), there is a further need to better understand the physical activity (PA) outcomes of games or sport lessons whilst using different teaching approaches within a PE context.

Physical activity in GBAs and TAs

PA levels could often be considered a by-product of the design of a games unit (Miller et al., 2016), yet PA is an essential outcome for students to address the adverse impact that inactivity can have on health and wellbeing (Lachytova et al., 2017; Ziaei et al., 2022). PE and organized sport within schools provide a structure for students to be physically active, and for many, this might be their only opportunity to participate in regular or weekly physical activity (Dudley et al., 2012; Skala et al., 2012). There is a limited amount of research comparing teaching approaches that aim to measure student activity in PE using pedometers (Miller et al., 2015; Rodríguez-Negro & Yanci, 2020), observational tools such as the System for Observing Fitness Instruction Time (SOFIT) (Miller et al., 2016; Smith et al., 2015) and accelerometers (Harvey et al., 2015; Wang & Wang, 2018). Studies have generally focussed on identifying student PA levels by classifying movement into time spent on low, moderate or high/vigorous intensity exercise with some research comparing this to recommended PA guidelines (Smith et al., 2015). Some studies comparing the PA of students during a GBA and TA have reported that GBAs involved higher levels of moderate to vigorous PA (MVPA) (Harvey et al., 2015; Wang & Wang, 2018). Whilst the use of combined versus single gender classes has been debated for some time, mostly from a skill development perspective (Gutierrez & García-López, 2012; Kirch et al., 2021), some research has shown that boys are significantly more active than girls in PE combined classes (J. M. García-Ceberino et al., 2020; Harvey, Smith, et al., 2016), and girls participate more actively when in single-gender classes (Vargos et al., 2021). To date, there is little research that compares the PA levels between a GBA and TA of students in an all-girls' PE games unit.

Although TAs have traditionally been predominant in the teaching of PE (Barba-Martín et al., 2020), the use of GBAs have been increasing in popularity (Barquero-Ruiz et al., 2020; Breed et al., 2024). Research comparing PA levels of students in TAs and GBAs using a thematic approach, particularly in single-gender classes is important, particularly using direct measures of activity such as GPS to develop a better understanding of these approaches and their influence on PA in PE. This study aims to compare the PA of primary school girls in a single-gender PE class during a GS thematic invasion unit and a traditional (TA) sport invasion unit.

Method

Participants and study design

Ethics was approved through Swinburne University (No: 20226237–9609). Students of an all-girls' independent primary school in south-east Melbourne, Australia, in years 5 and 6 participating in Physical Education classes were recruited, with a chronological age of 10 to 12 years ($n = 67$). Permission was first granted by the school principal prior to receiving parental consent via an online portal and finally student assent ($n = 66$). This current study was conducted during the regular scheduled PE class times in term 2 (from 26th April to 24th June) but was part of a larger year-long research project. A quasi-experimental design was utilized whereby students remained within their normal PE groups with the class randomly allocated to either a GS or TA 7-lesson intervention, with one year 5 and one year 6 class in each intervention (GS $n = 34$, TA

$n = 32$). Only PA data from students with a complete set of GPS data (i.e., completed the whole lesson) from all of lessons 3,4 and 5 of the interventions (GS $n = 14$, TA $n = 13$) were used for analysis.

Positionality statement

The research team comprise a Professor, Senior Lecturer, Lecturer, and Physical Education Teacher all with interest in considering the applied values of cognitive and ecological views of motor learning and control and how these influence skill acquisition approaches.

Procedures

The teacher (AK) and lead researcher (RB) co-designed 7-lesson invasion game units (each lesson was 60-minutes of planned activity) for each intervention: (a) GS thematic unit, and (b) TA sport unit. The GS unit was developed based on a previously published invasion games thematic unit, encompassing small-sided generic designer games and task-constraint manipulation (Breed & Spittle, 2021). The TA lessons were developed specific to two sports (netball and basketball) using a direct instruction/technical skill model and guidelines adapted from Metzler and Colquitt (2021). Both units were designed to encompass the key ball skills of throwing, catching and ball bouncing and were formulated within the Australian Curriculum (Version 8.4) Health and Physical Education context. Units were organized within the years 5 and 6 "movement and physical activity" strand and incorporating the sub-strands of "moving our bodies," "making active choices" and "learning through movement" (Australian Curriculum, Assessment and Reporting Authority [ACARA], 2022). To verify validity, two other researchers (MS, DO) and two experienced PE teachers from other schools provided feedback on the content of each unit and used a checklist to validate each unit intervention (Supplement 1). A brief overview of each unit intervention is shown in Table 1.

Classes were taught by the students' regular PE teacher (AK) with 22 years of teaching experience in primary PE. Prior to undertaking the research, an interview was conducted and recorded by the lead researcher (RB) with the teacher to gauge their level of understanding and expertise, with the

Table 1. Overview of unit interventions.

Invasion Game Sense Unit *(Ref: Breed & Spittle (2021) Ch. 7–8).*		
Lesson Focus (Learning)	*Example Content*	*Key Questions/Themes*
Lesson 1. Understanding invasion games. Keeping possession.	Introduction to invasion game sense. End-zone (end-to-end). 2v1 keeping off. End-zone (half-court).	Similarities of invasion sports? How do turnovers relate to scoring? When to pass? Where to run? When to run?
Lesson 2. Keeping possession. When to pass. How to pass.	2v1 keeping off. Gauntlet (2v1). Rebound ball (half-court). Rebound ball (end-to-end continuous).	Importance of keeping possession? When to pass? How to pass? When to shoot or pass?
Lesson 3. Concept of space. Where to run. How to create space.	2v1 Gauntlet. 2v1 Gauntlet with rebound. 3v1/3v2/3v3 End-zone (half-court).	What is space? How to create space? When to pass? Where to pass? How to pass? When to pass vs dribble?
Lesson 4. When to pass, run/dribble or shoot?	4 corners. 4v2 Keeping off. Rebound ball (half-court).	How to create space? When to pass? When should you shoot? When should you run/dribble?
Lesson 5. Moving into space. Decision-making with the ball.	4 corners. King pin. Guard the pins (half-court). Guard the pints (end-to-end).	How to create space? How do we keep possession? Why is this important? When to pass, dribble or shoot?
Lesson 6. Decision-making with the ball. Creating team strategies.	King pin. 2v1 keeping off. The mixed bag.	What type of passes are best? When should you shoot? How were all the games similar? What worked well?
Lesson 7. Transfer of technical and tactical skills. Game similarities.	4v2 Keeping off. End zone (half-court). The mixed bag. Conclusion and review.	What skills have transferred between games? How is each game similar in tactics? What key strategies are similar?
Technical Sport Unit		
Lesson Focus (Learning)	*Example Content*	*Key Teaching Points/Themes*
Lesson 1. Netball. Catching a netball. Performing a chest pass. Footwork rule.	Dodge and steal (W-up). Aussie Diamonds (pair pass). Fast Aussie Diamonds (4's pass). Diamond netball (diamond pass). 3v3 Endzone netball.	Evasive skill technique (dodge). Stationary catch (eyes on ball, hands ready, "give"/bring to chest). Chest pass (thumbs behind ball, step forwards, extend). Footwork rule/pivot foot.
Lesson 2. Netball. Shoulder pass. Maintain possession. Contact, obstruction rules. Court positions.	Pairs netball scramble (W-up). Aussie Diamonds (shoulder pass). Fast Aussie Diamonds (shoulder pass). 4 corners. Goal circle ball (half-court).	Revision of chest pass, catch and footwork. Shoulder pass (step opposite foot, ball behind shoulder, follow through). Defend 1 m from ball carrier.
Lesson 3. Netball. Bounce pass. Shooting. Netball positions and restarting game from center.	Passing increase the distance (W-up). Fast Aussie Diamonds. 30-sec bounce pass game. Hoop shooter. Goal sharpshooter.	Shoulder pass revision. Bounce pass (step, push ball forward and downward, release at hip, bounce 2/3 away). BEEF shooting acronym (balance, eyes, elbow, follow through).
Lesson 4. Basketball. Passing with chest, bounce and overhead. Catching. Jump stop/triple threat. Dribbling.	Shooting vs bounce pass (W-up). Jump stop, stride stop, triple threat with/out ball. Stationary dribble. Traffic light dribble. End-zone b/ball (half-court).	Revision of passing from netball. Revision of BEEF shooting. Jump stop (catch then land on two-feet). Stride stop (one-two step). Triple threat (protect ball). Travel rule (pivot foot).
Lesson 5. Basketball. Passing accurately. Shooting.	Follow the leader dribble (W-up). Slalom dribble relay. Partner passing. Jump stop, pivot, pass. Shooting into hoop, then ring. Numbers b/ball.	Revision of dribbling. Rules—travel, double dribble (using 2-hands on ball). BEEF shooting acronym (using legs for power). Fouls (e.g., contact).
Lesson 6. Basketball. Running shot (lay-up). Maintaining possession. Restarting game from stop plays (e.g., score, foul).	Jump stop shooting (W-up). Lay-up technique with/out shot. 4v2 b/ball. 3v3 b/ball half-court.	Lay-up (1–2-jump, opposite leg to arm, leg drive, extension, release, aim for top of square). Jump ball rule. Foul (take from sideline).
Lesson 7. Netball and basketball. Evasion. Lead and create space.	Lay-up bowls (W-up). Dodging zig-zag drill. Escape game. Dodge and receive 1v1 in square. 3v3 b/ball. Half-court netball.	Revision of lay-up. Dodge (push off outside foot, lower body, turn hips to direction of travel). Moving into space then calling for ball. Similarities between netball and basketball.

following findings: the teacher demonstrated (1) knowledge and understanding of both teaching models, (2) had no preference or bias for either model, but tended to use a variety of mixed approaches, (3) was experienced in teaching a variety of games and sports from different game categories to primary-aged girls, and (4) taught games as single sport units to this age group. Prior to teaching the games units, the teacher had two professional development sessions with the lead researcher (RB) to reinforce and discuss the pedagogy of each model. One lesson of each teaching approach was video-recorded prior to the first unit intervention lesson to provide feedback and assess the validity of each method using a modified checklist (Turner & Martinek, 1999) (Supplement 2). The same checklist was used by the lead researcher to observe one GS and one TA lesson in weeks 1, 3 and 5 to ensure fidelity of each teaching approach.

Instrumentation and data collection

Student PA levels were measured using SPT2 wearable devices (SPT, Sport Performance Tracking, Australia) containing a 10 Hz GPS tracker and 100 Hz tri-axial microsensors (accelerometer, gyroscope, and magnetometer). Students wore a specialized vest (that holds the GPS unit in place on the upper back) over their sport shirt during every lesson. The devices measured total distance, distance covered in each speed zone, maximum speed and 3D load (accelerometry-derived external load that sums forwards-backwards, lateral and vertical forces). Work rate (average speed) was also calculated to compensate for any minor time differences spent in the lesson, measured by the distance divided by time (m/min). The speed zones were customized to suit this age and gender, based on previous work done by the researchers using GPS in schools (Table 2).

The data for each lesson was firstly cropped (e.g., lesson start and end points to the nearest minute) using the SPT GameTraka software then exported to Microsoft Excel (Microsoft Office 365) for data sorting and management. Only data from students with complete data sets from lessons 3,4 and 5 were analyzed in this study (GS $n = 14$, TA $n = 13$).

Statistical analysis

The dependent variables were included in a mixed design ANOVA with 2 levels on the independent factor of pedagogy (TA and GS) and three levels on the repeated measures factor of lesson (Lessons 3, 4, and 5). In cases of sphericity violation Greenhouse-Geiser adjustments were made to the degrees of freedom. To follow-up interaction effects, planned contrasts were carried out to test if the outcome was dependent on the intervention level when going from lessons 3 to 5. Main effects of lesson and interaction effects were also followed up with post-hoc analyses where two-tailed independent t-tests were used to test for differences between pedagogy intervention at each lesson and two-tailed dependent t-tests were used to compare lessons 3 and 4, 4 and 5, and 3 and 5. Post-hoc tests were subjected to Bonferroni corrections to control for inflation in type I error. Effect size r was calculated for all focused comparisons, where for the main effect of pedagogy, $r = \sqrt{(F/(F + df_R))}$, noting that df_R refers to the residual degrees of freedom (N-2), and t-tests, $r = \sqrt{(t^2/(t^2 + df))}$. To interpret the effect size r, values between .1 and .3 are considered small, values between .3 and .5 are medium, and values greater than .5 are large. Finally, power analysis was performed assuming a large effect size (and beta = 0.8 and $p < .05$). A critical value of f = 3.63 (assuming large effects, f = 0.5) with N = 10 was required for the repeated measures factor to be sufficiently powered. For the independent factor, a critical value of f = 4.3, with N = 24, and assuming large effects (f = 0.5) was needed for sufficient power.

Results

A summary of outcomes and are presented to Table 3.

The significant main effects of pedagogy revealed that the GS group traveled a greater distance ($M = 1799$ m, SD = 32) across all lessons ($F(1,25) = 19.67$, $p < .001$, $r = 0.66$) compared to the TA group ($M = 1596$ m, $SD = 33$). The GS group also had a significantly higher work rate ($M = 28$ m/min, $SD = 1$) across all lessons ($F(1,25) = 20.57$, $p < .001$, $r = 0.67$) compared to the TA group ($M = 25$ m/min, $SD = 1$). The GS group had a significantly higher distance traveled in activity Zone 2 ($M = 789$ m, $SD = 23$) across all lessons ($F(1,25) = 33.17$, $p < .001$, $r = 0.76$) compared to the TA group ($M = 599$ m, $SD = 24$). Finally, the GS group revealed a significantly higher 3D Load ($M = 206$, $SD = 7$) across all lessons ($F(1,24) = 4.51$, $p = .04$, $r = 0.40$) compared to the TA group ($M = 186$, $SD = 7$). All other outcomes (i.e., distance traveled in zones 1, 3, 4, and 5, and top speed) showed no significant difference between the GS and TA groups (outcomes are visualized in Figure 1).

There were also several significant main effects of lesson. These showed that distance traveled in activity Zone 1 significantly decreased across lessons, irrespective of which group the participants belonged to, $F(2,50) = 7.71$, $p = .001$, $r = 0.37$. Additionally, distance traveled in Zone 2 significantly increased across lessons, irrespective of which group the participants belonged to, $F(1.6,50) = 3.98$, $p = .04$, $r = 0.27$. Finally, there was also a main effect of lesson on 3D load, which decreased across lessons, irrespective of which group the participants belonged to, $F(2,48) = 3.75$,

Table 2. GPS speed zones.

Zone	Definition	m/s	km/h
1.	Recovery	<0.6	<2.2
2.	Walk/Adjust	0.6–1.7	2.2–6.1
3.	Jog	1.7–2.8	6.1–10
4.	Run	2.8–3.9	10–14
5.	High-speed run	3.9+	14+

Table 3. Physical activity outcomes for intervention groups across each lesson.

	Traditional (TA) ($N = 13$)				Game sense (GS) ($N = 14$)			
	M ± SD	Lesson 3	Lesson4	Lesson 5	M ± SD	Lesson 3	Lesson 4	Lesson 5
Distance (m)[*,^]	159 ± 33	1538 ± 189[a]	1621 ± 31[b]	1627 ± 101	1799 ± 32	1848 ± 152	1817 ± 168	1731 ± 40[3G]
Time (mins)	63.3	62.5	65	62.5	63.3	62.5	65	62.5
Work rate (m/min)[*,^]	25 ± 1	24 ± 3[a]	25 ± 2[b]	26 ± 2	28 ± 1	29 ± 2	28 ± 3	28 ± 3[3G]
Zone 1 (m)[#,^]	697 ± 12	688 ± 47[1T]	736 ± 45[2T]	677 ± 28[c]	719 ± 11	687 ± 49	713 ± 48	757 ± 70[3G]
Zone 2 (m)[*,#]	599 ± 24	608 ± 163[a]	607 ± 57[b]	582 ± 43[c]	789 ± 23	814 ± 33	822 ± 128[2G]	732 ± 26[3G]
Zone 3 (m)[^]	227 ± 12	176 ± 39[a]	219 ± 55[2T]	285 ± 50[c,3T]	237 ± 11	276 ± 75	239 ± 55	198 ± 58[3G]
Zone 4 (m)[^]	64 ± 7	58 ± 26	60 ± 32	74 ± 38	48 ± 7	62 ± 34	41 ± 27	42 ± 29[3G]
Zone 5 (m)	9 ± 2	8 ± 8	9 ± 10	9 ± 10	5 ± 2	9 ± 4	3 ± 4	3 ± 4
Top speed (m/s)	4.7 ± 0.1	4.6 ± 0.7	4.6 ± 0.9	4.8 ± 0.9	4.4 ± 0.1	5.0 ± 1.2	4.1 ± 0.5	4.2 ± 0.6
3D load[*,#]	186 ± 7	182 ± 27	195 ± 29	181 ± 30	206 ± 7	211 ± 25	213 ± 27	194 ± 28

% = Median and interquartile range given; *= pedagogical intervention effect; #= session effect; ^= interaction effect; a = between-group comparison between traditional and game-sense approach on session 1; b = between-group comparison between traditional and game-sense approach on session 2; c = between-group comparison between traditional and game-sense approach on session 3; 1T = within group comparison between session 1 and session 2 (Traditional group); 2T = within group comparison between session 2 and session 3 (Traditional group); 3T = within group comparison between session 1 and session 3 (Traditional group); 1 G = within group comparison between session 1 and session 2 (Game-sense group); 2 G = within group comparison between session 2 and session 3 (Game-sense group); 3 G = within group comparison between session 1 and session 3 (Game-sense group).

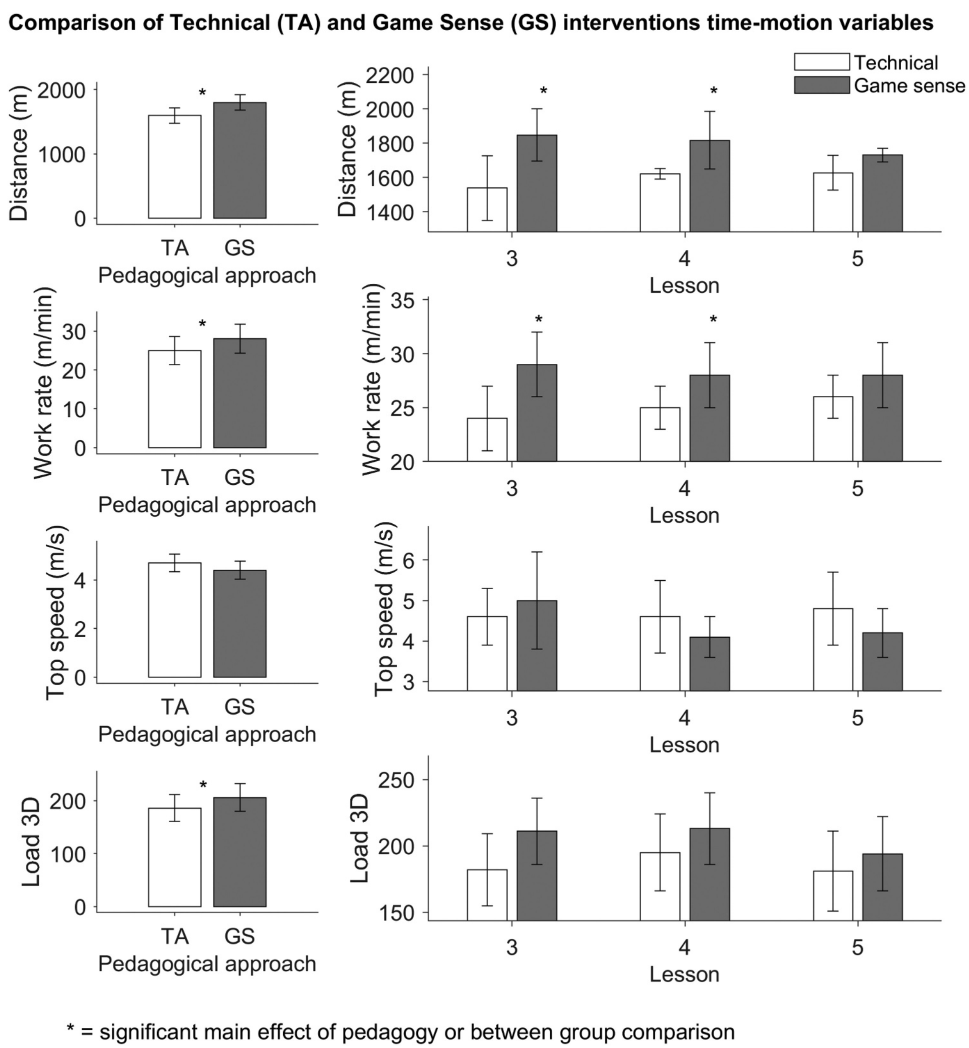

Figure 1. Comparison of time-motion variables between Technical Approach (TA) and Game Sense (GS) interventions.

$p = .03$, $r = 0.27$. All other outcomes (i.e., distance traveled, work rate, distance traveled in zones 3, 4, and 5, and top speed) showed no significant effect of lesson (refer to Figure 2 for lesson effects).

Significant interaction effects were also revealed. These showed that outcomes of distance traveled ($F(2,50) = 6.01$, $p = .005$, $r = 0.44$), work rate ($F(2,50) = 6.68$, $p = .003$, $r = 0.46$), and distance traveled in activity Zones 1

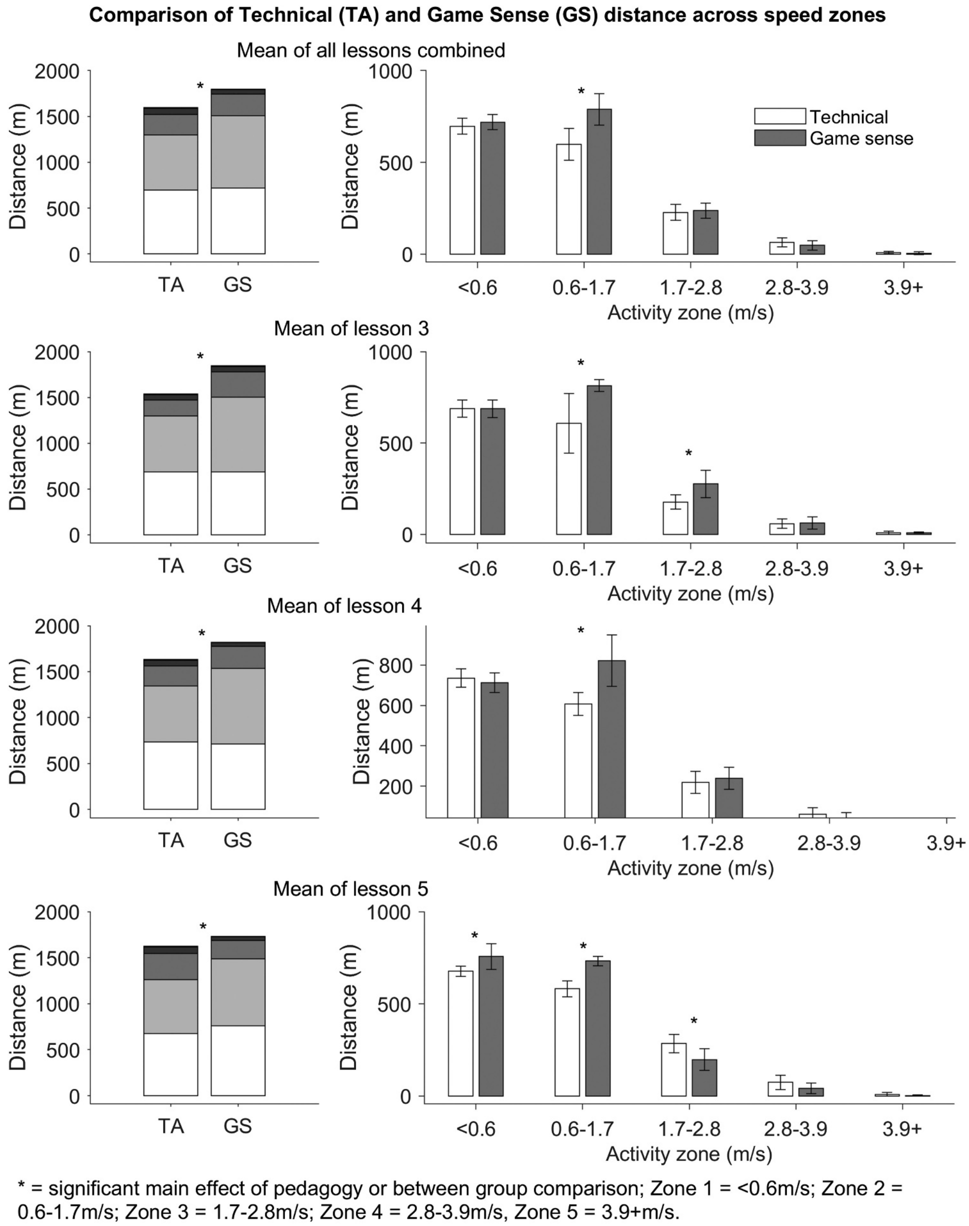

Figure 2. Comparison between interventions across lessons on distance covered in each activity zone.

($F(2,50) = 15.72$, $p < .001$, $r = 0.62$), 3 ($F(2,50) = 27.20$, $p < .001$, $r = 0.72$), and 4 ($F(2,50) = 5.18$, $p = .009$, $r = 0.41$) were dependent on group and lesson in combination. The planned contrast for distance indicated that the interaction effect for distance was driven by a reduction across lessons 3 ($M = 1848$ m, $SD = 152$) to 5 ($M = 1731$ m, SD = 40) in distance traveled in the GS group in contrast with no change in distance traveled in the TA group from lessons 3 ($M = 1538$ m, $SD = 189$) to 5 ($M = 1627$ m, $SD = 101$), $F(1,25) = 19.67$, $p < .001$, $r = 0.66$. The planned contrast for work rate also showed that the interaction effect for work rate was driven by a reduction in work rate across lessons ($M = 29$ m/min, $SD = 2$) to 5 ($M = 28$ m/min, $SD = 3$) in the GS group, contrasting with no change in work rate the TA group from lessons 3 ($M = 24$ m/min, $SD = 3$) to 5 ($M = 26$ m/min, $SD = 2$), $F(1,25) = 4.52$, $p = .04$, $r = 0.39$. The interpretation for the interaction terms were also supported by the Bonferroni corrected post-hoc tests summarized to Table 1 (alongside the means and SDs of each lesson for each group).

Discussion

The purpose of the study was to compare the PA levels of students participating in a GS thematic invasion unit and a TA sport invasion unit in all-girl's primary PE classes. The research question aimed to determine which teaching approach fosters higher PA levels in single-gender PE classes. Based on limited research, it was expected that overall levels of activity would be higher in the GS group compared to the TA group (Harvey, Smith, et al., 2016; Smith et al., 2015). Exploratory analysis was designed to investigate underlying areas of differences in PA levels as well as to consider the effect of time on PA between groups.

Game sense fosters greater PA than a technical approach in girls during PE lessons

The findings supported the main hypothesis, revealing that students in the GS group demonstrated significantly higher PA levels in terms of distance traveled, work rate, and 3D load, when compared to the TA group. The work rate or average speed (distance covered within the lesson time) was calculated to account for any possible differences between group distances during each lesson and to incorporate both intensity and duration of the activity. The results are generally consistent with previous research, mostly conducted within coeducational settings, that have shown higher levels and intensities of PA when using GBAs (such as GS) to teach a single sport (e.g., basketball, soccer) when compared to traditional curriculum-based approaches (Gamero et al., 2021; Harvey, Smith, et al., 2016; Harvey, Song, et al., 2016; Miller et al., 2016) (although see Rodríguez-Negro & Yanci, 2020).

Our study was unusual in that it used direct externally quantified load measures (e.g., distance and 3D load) collected via GPS units and therefore a direct comparison with research using alternative methods of data collection, such as accelerometry (e.g., Harvey et al., 2015; Smith et al., 2015) or direct observation (e.g., Harvey, Song, et al., 2016; Miller et al., 2016), should be exercised with caution. External load is the actual work done during movement (e.g., distance, acceleration, accumulated forces) and includes both intensity and duration, whereas internal load is the body's response to any external load (e.g., heart rate, perceived exertion). Some research has shown an association between various external and internal load measures (McLaren et al., 2018). Only two other studies were identified to have compared the PA of a GBA and TA using GPS units within PE, both showing that PA was greater using a GBA within coeducational classes (Gamero et al., 2021; J. M. García-Ceberino et al., 2020). Our results also supported findings that GBAs are associated with more PA than TAs in studies that have used observational techniques (Song et al., 2016), pedometers (Miller et al., 2015) and accelerometers (Harvey & García-López, 2017; Miller et al., 2019).

Additional analysis revealed that activity primarily in Zone 2 (2.2–6.1 km/h) was the principal driver for the main effect difference between intervention groups on PA outcomes, where significantly greater distance was traveled in Zone 2 in the GS group. Similarly, a study using accelerometry in junior soccer players showed that a GBA produced significantly more low-intensity PA than a TA, but not moderate or vigorous PA (Sierra-Ríos et al., 2020). One limitation of using distance covered in each zone as a definition of PA intensity during small-sided games is that it does not consider the rapid changes of speed and directional movements. For this reason, 3D load (accelerometry-derived measure of accumulation of forces) was also measured as it provides a good indication of exercise intensity, further supporting other research that the GS approach was more conducive to promoting higher levels of PA than the TA (J. M. García-Ceberino et al., 2020; Harvey, Smith, et al., 2016). It is therefore reasonable to assume that the increased distance covered in Zone 2, combined with an increase in 3D load, during the GS intervention was likely a result of more change of direction, acceleration, and deceleration movements at slower speeds, consistent with findings of higher levels of moderate and vigorous PA (MVPA) when playing in small-sided games (Harvey & García-López, 2017).

Consideration of gender on PA levels

A key difference of the present study is that the intervention was conducted in an all-girls' primary school. Previous research on gender differences in PE classes has indicated that girls tend to engage in less PA than boys within coeducational lessons (J. M. García-Ceberino et al., 2020; Harvey, Smith, et al., 2016; van Beurden et al., 2003). For instance, van Beurden et al. (2003) showed that primary school boys averaged 5.5% greater MVPA than girls, and Harvey, Smith, et al. (2016) demonstrated that primary school boys were involved in 6.7% more MVPA than girls, and 9% more MVPA of boys at secondary school. Interestingly, girls have been previously shown to exercise at higher intensities during single-gender classes when compared to coeducational settings (Vargos et al., 2021). In contrast to our findings, one study compared GBA and TA interventions in year 7 girls in single-gender PE and found that a GBA unit was not significantly better than a TA for fostering MVPA (using accelerometry) in either netball or football (soccer) (Smith et al., 2015). In a community sport single-gender setting of girls aged 8 to 12 years, a GBA did foster a higher MVPA than a TA when measured using a validated self-report tool (Farmer et al., 2020). Hence, in the context of the limited literature of comparing teaching approaches within single-gender PE classes, our study provides some evidence favoring GS as an approach to teaching and learning invasion games as more effective in promoting PA than a TA among female primary school students.

Implications for PE curriculum and pedagogy frameworks of learning and teaching

The findings of this study have important implications for PE curriculum design aiming to enhance PA, particularly for single-gender classes. Incorporating a GS thematic invasion unit can be more effective than traditional sport units in promoting PA and in addition provide other positive learning outcomes, such as skill development (Miller et al., 2016) and motivation/enjoyment (Wang & Wang, 2018). Increasing activity in specific zones and specific movements (e.g., changes of direction) may also relate to opportunities for skill development and enjoyment (although this question remains unexplored in the literature). For example, greater PA may promote more opportunities to act in the context of game play. This may yield (simply by virtue of greater activity) a broader exploration of motor problems and their solutions (Orth et al., 2017). However, the implementation of GS may present challenges in the PE context. For instance, there may be a need for additional teacher training and better understanding to ensure fidelity of the approach (Barba-Martín et al., 2020), as well as potential resistance to change from current teaching methods either at a teacher or curriculum level. Even an experienced teacher (as in this study) commented about the challenge of ensuring fidelity when utilizing the GS method as opposed to a traditional teaching approach. To address these challenges, future research should collaborate with schools and education systems to explore current gaps in professional development and develop evidence-based strategies for developing up-to-date approaches to addressing challenges such as PA levels and skill learning during PE classes.

Limitations and future research

While the present study provides insights into the effectiveness of GS teaching in single-gender PE classes for increasing PA, there are several limitations. Although sufficiently powered, the relatively small sample size limits the ability to fully leverage the findings (using multiple-regression analysis for instance). Furthermore, while every effort to control for bias were taken, it is possible the teacher's prior experiences may introduce biases in the outcomes. Finally, as this study focused on PE in the context of primary school girls, this limits the generalizability to other settings or age groups.

Several avenues of future research that might be fruitful include investigating the long-term impact of GBAs (e.g., GS, TGfU) on skill development, psychosocial outcomes, and PA levels to better understand the combined benefits and interrelationships of these student outcomes. Another key area would be to improve our understanding of the influence of initial skill levels and their interaction with PA outcomes. For instance, is it beneficial to form learning groups that have relatively homogenous skill levels, or should groups be diversified (Orth et al., 2019)? Related to this issue, is to assess integrated approaches. For example, it has been a longstanding issue to investigate how to optimize or justify the integration of fitness-based activities with PE lessons to further enhance PA levels (and whether this is even needed?), while maintaining a focus on skills and motivation consistent with the goals of PE principles (Wormhoudt et al., 2018). Finally, related to this concern is to investigate the nature of the relationship between PA and other positive outcomes, such as skill development, motivation/adherence, and engagement.

Conclusion

This study indicated that the GS thematic invasion unit was more effective in promoting PA levels in all-girl primary PE classes than traditional sport-based invasion units. The findings suggest that alongside the commonly advocated benefits of GS such as engagement, tactical awareness, and potentially better confidence to move, GBAs such as GS may also support increased activity levels by providing opportunities to participate more actively in invasion games. These outcomes have important implications for PE curriculum and pedagogy frameworks, especially for single-gender classes. In developing a strengths-based approach to physical education that teaches the values of movement it would be beneficial to consider PA outcomes in addition to skill development and affective outcomes when planning lessons and units, including how they can be measured quickly and reliably in PE classes. The study also highlights the need for continued research in areas such as long-term impacts of GBAs, the consideration of integrated approaches within PE lessons, and understanding the relationship between PA and other potential outcomes from pedagogical approaches in PE. By addressing these research gaps and potential limitations, educators and researchers can work together to develop and implement more effective teaching approaches that promote PA in conjunction with key learning outcomes for students in diverse populations and settings.

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