Adapting Badminton Court Dimensions to Enhance Physical Activity in Physical Education

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Manuscript title

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Date of submission: 29th of March 2025

Abstract

Purpose: Enjoyment in Physical Education represents a critical factor for increasing students' Physical Activity (PA) levels. Designing game-formats using a Constraints-Led-Approach fostering richer experiences for all students, may help achieve this goal. This study examines how interaction effects between variations in the size of the playing area and student characteristics (e.g., sex, skill level) influence both PA levels and enjoyment in badminton. **Method:** 254 students participated in three badminton game formats where court size was varied: "singles full court" (SFC), "singles half court" (SHC) and "doubles" (DB).

Results: Main results showed that PA generated in the SFC fell into the 'vigorous' category, but the analysis of interactions between environmental and individual constraints revealed how they modify this "area" effect.

Discussion/Conclusion: Results underscored the importance designing playing area dimensions in games (e.g. with a hybrid "accordion" format) to align with the specific needs of students, thereby enhancing PA levels.

Keywords: Engagement, Affective Learning Design, Constraints-Led Approach, Game Formats

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Introduction

Enjoyment, a lever for physical engagement

Promoting physical activity (PA) is a key strategy for improving public health, yet recent epidemiological data revealed alarmingly high levels of physical inactivity among adolescents (WHO, 2023). Physical Education (PE), within the structure of their formal education, serves as a key opportunity for adolescents to engage in PA (Derigny et al., 2022). However, despite this potential, research indicates that PA levels during PE classes are often insufficient (Fairclough and Stratton, 2004). A growing body has shown that participation enjoyment plays a crucial role in motivating adolescents to engage in PA (Lonsdale et al., 2013). So, one possible explanation for students' disengagement may result from a lack of interest generated in PE, leading to insufficient intensity of PA (Beale et al., 2021), which may be damaging, given the growing recognition of benefits of vigorous physical activity (VPA) for public health (Sanchez-Lastra et al., 2024). Thus, further research is needed to investigate the effectiveness of interventions in PE settings designed to improve enjoyment and physical engagement (Dieu et al., 2020a). Designing game-formats using a Constraints-Led-Approach (CLA), considering interactions between student characteristics and environmental variables, to foster richer experiences for all students (Rudd et al. 2020), may help achieve this goal, specifically in badminton (Dieu et al., 2025).

The constraint approach to understanding engagement to PE formats

The CLA is a prominent pedagogical approach framed by the theory of ecological dynamics, originating within the field of motor learning through the fusion of complexity sciences, dynamical systems theory, and ecological psychology (Button et al. 2020). CLA has gained increasing attention to move beyond studies that focus solely on individual or environmental variables when exploring participant engagement in PE (Dieu et al., 2025). This approach offers a holistic (Rudd et al., 2020) and ecological (Davids et al., 2008) pedagogical model to enhance skill acquisition, viewing learners as complex, adaptive dynamic systems engaged in continuous interactions with their environment. Within the CLA, engagement in PA emerges from continuous interactions between three categories of constraints: organismic constraints (related to each learner's physical, physiological, and cognitive characteristics); environmental constraints (such as location, type of environment, social factors, and space); and task constraints (including rules, equipment and specific goals) (Renshaw et al., 2010). Thus, analysis of participant engagement focuses on the continuous interplay between these three types of constraints which facilitate each individual's transactions (Seifert et al., 2023) with the playing environment in contexts like badminton. This model has been applied recently to better understand engagement in both sports (Headrick et al., 2015) and PE (Dieu et al., 2025), particularly through the lens of "affective learning design" (designing activities for meaningful engagement in sport; Headrick et al., 2015: 83). In designing an affective learning environment, the role of the teacher shifts from prescribing specific behaviours to "designing the constraints of learning formats (Woods et al., 2022), tailoring them to meet the specific needs of learners in order to foster meaningful engagement (Dieu et al., 2025).

The potential contribution of the CLA to the analysis of engagement in badminton

Previous research has extensively demonstrated the impact of individual variables on students' engagement in PE. In badminton, the role of expertise has been a focus of recent studies which have shown that the PA engagement measures of the most skilled students were systematically higher than those with lower measures (Dieu et al., 2020b). Sex differences have also been explored, with studies indicating that boys tend to expend more energy than girls during badminton games (Bebetsos and Antoniou, 2012). In addition to individual factors, environmental variables, such as the social context (e.g. type of communication between students, see Dieu et al., 2022) and the goals of the specific activity (Dieu et al., 2020a), are highly important influences on student engagement in badminton For example, Dieu et al. (2020a) found that a format where the objective is to win a singles match by accumulating points for a team result in higher PA levels than a singles format with a handicap-based goal. From an ecological perspective, analysis of student engagement cannot be reduced to recording individual or environmental variables in isolation; rather, it must focus on the interactions between these factors. Recent research has shown that the interplay between organismic and task constraints can significantly influence PA levels, suggesting that modifications in badminton teaching formats are most important because they can directly affect students' physical engagement (Dieu et al., 2025). Continuing a line of research initiated by Dieu et al., in 2020, a follow-up study in 2022 revealed that interactions between individual and environmental variables tended to impact the PA scores of skilled boys only. Furthermore, the findings of this study challenged the traditional view of sex differences in PE, revealing that skilled girls also enjoy competitive play formats as much as cooperative ones. In addition, recent research highlights how interactions between individual and environmental variables can significantly reorganize psychological engagement (e.g situational interest, see Roure and Dieu, 2022) depending on the format. Thus, students' engagement in badminton evolves, based on the dynamic interaction between environmental factors and organismic variables. While the effects of interactions between game format objectives and participants' expertise levels have been explored (Roure and Dieu, 2022), one key environmental variable remains understudied in badminton: the dimensions of the playing area. This is notable, as "game area" has been identified as a strong determinant of student engagement (Visioli et al., 2024).

Effect of the area - 'individual' interaction in opposition sports

In competitive sports, the dimensions of the playing area and the number of players involved in a game format significantly influence both the quantity and intensity of PA.

Research has demonstrated the positive effects of playing on smaller areas on physical engagement in team games (Clemente et al., 2017; Zouhal et al., 2020). Moreover, small-sided games formats are often perceived as more interesting (Selmi et al., 2020). However, Dieu et al.'s (2022) research on badminton presented a different picture. Their findings aligned with previous studies showing that doubles play-despite being played on a smaller court- resulted in significantly less PA than singles (Alcock and Cable, 2009). Furthermore, doubles formats are not regarded as more enjoyable than singles played on a larger court. Thus, although these studies highlighted the impact of the playing area's size on PA, two key limitations remain: (a) the effects of increased versus reduced playing space on PA show contradictory outcomes across different sports, and (b), the interaction of individual factors (e.g., expertise) is often overlooked, despite its potential to further influence engagement outcomes.

Badminton teaching and the impact on area-individual interaction

Badminton, particularly as it is both physically demanding (Phomsoupha and Laffaye, 2015) and appealing to students of all ages (Grice, 1996), is often considered a viable means of fostering better engagement among students in physical activity. However, the standard game format—singles play on a full-size court—limits the number of students participating simultaneously due to large class sizes (e.g., in a typical Type C gymnasium, which accommodates seven regular courts, only 14 students can play at a time). This spatial limitation presents a challenge for PE teachers, requiring them to rethink how to optimize students' playing time on the court and reimagine locations for PA (Rothwell et al., 2024). Consequently, two alternative game formats are often used in badminton teaching—half-court singles or doubles—to allow more students to play simultaneously. However, the effects of these three formats on students' enjoyment and PA levels, particularly across different student profiles, remain under investigated in research. Teachers' decisions to adopt one format over another are often based on professional beliefs about the assumed impact of each format, rather than on empirical evidence regarding their influence on student engagement in sport classes.

Purpose of the study

From an ecological perspective, this study aimed to examine how interaction effects between variations in dimensions of the playing area (doubles, large-court singles, or half-court singles) and students' individual characteristics (sex and expertise level), influence both PA levels and participation enjoyment among students in PE badminton unit.

Methods

Participants

A total of 254 secondary school students (aged 10 to 18 years; Mage = 13.2 ± 1.7 years; 48% female), voluntarily participated in this study, presented in Table 1. Observations were conducted by nine certified PE teachers (four males and five females) from seven middle schools and two high schools in X.

[insert Table 1]

For each student, the study protocol consisted of the following steps: (a) participating in a badminton unit comprising three sequences, each featuring three different game formats; (b) playing at least three matches in each format against an opponent from the same performance level group to avoid a significant imbalance between players; (c) wearing an accelerometer; and (d) completing a validated X-language questionnaire immediately after each game sequence. Students who did not participate in all three formats or who failed to complete the questionnaire accurately (e.g., incomplete items) were excluded from the analysis. In compliance with X law and the European General Data Protection Regulation, the study received formal approval from the ethics committee of our institution. Parents of all participating students were informed about the study's objectives, and written consent was obtained from each of them.

Designing badminton game formats

According to official badminton rules, the standard court area measures 69.68 m² for singles (5.20 m wide and 13.40 m long) and 81.74 m² for doubles (6.10 m wide, with the same length). In singles play, each player is responsible for covering approximately 34.84 m², whereas in doubles, each player covers about 40.87 m². To manipulate the environmental constraint related to the playing area, three competitive situations were implemented in the PE unit: (1) Singles on a Full Court (SFC): Players participated in one-on-one matches on a full singles court, requiring each player to defend an area of 34.84 m², (2) Singles on a Half-Court (SHC): Like the SFC format, players took part in one-on-one matches, but this time on a half of a standard court, with each player responsible for defending an area of 17.42 m², (3) Doubles (DB): In this format, students played in pairs (two against two) on a full doubles court. Each pair is responsible for defending a shared court area of 40.87 m².

Standardization of badminton sessions

Prior to the study, training sessions were conducted for the teachers involved. To classify participants, we applied a skill-level typology known as conative classification, specifically developed for badminton (Dieu et al., 2020b) (see Table 2). The classification was based on three components: a) Physical Component: Evaluated using rally duration (Dieu et al., 2020b). b) Tactical Component: Assessed through shuttlecock trajectories and the ratio of forced to unforced errors (Phomsoupha and Laffaye, 2015); and c) Technical Component: Examined by recording key movements, particularly arm and trunk gestures during overhead forehands (Wang et al., 2009). Based on these observations, participants were categorized into one of five conative stages: (1) structural, (2) functional, (3) technical, (4) contextual, or (5) expertise, following the criteria outlined by Dieu et al. (2020b). Teachers were initially trained to classify students into the first three conative stages, as stages 4 and 5 are rarely observed in school settings. Training involved reviewing video clips of students playing badminton. Teachers were subsequently evaluated on their ability to accurately recognize these stages within a 5% error margin. During the study, all participants were video recorded during games, and their classifications were independently verified by two analysts: the trained teacher and a badminton specialist. To assess inter-rater reliability, Cohen's kappa was calculated, indicating substantial agreement between the two raters ($\kappa = 0.91$). In cases of disagreement, the analysts reviewed the video together with the principal researcher to reach a consensus. If no agreement could be found, the participant was excluded from the analysis. The classification process revealed that 101 students were categorized in the structural stage (stage 1), 111 in the functional stage (stage 2), and 38 in the technical stage (stage 3). To ensure the quality and consistency of instructional content, teachers' contributions were assessed using standardized learning design benchmarks. These included student objectives, activity descriptions, materials, sequence duration, and student organization. Additionally, to avoid any unintended influence of teacher activity on the enjoyment experienced by students, teachers were requested not to provide feedback (positive or corrective) to students during the learning design.

[insert Table 2]

Data collection

Data collection occurred during regularly scheduled PE lessons between October 2023 and December 2023. The badminton unit consisted of a minimum of eight lessons. During the first two lessons, students were observed for expertise classification and familiarized with wearing the actimetric belt. Then, data collection was conducted during six PE lessons over six weeks. Each student, from the same PE class, experienced the learning designs with a one-week interval between sessions (to avoid any proximity effects between them).

To ensure consistency: a) matches in each format lasted four minutes; b) each participant had to play against an opponent from the same performance level group (same conative stage) to avoid a significant skill-level imbalance between players; c) students are regularly reclassified in conative stages during the PE unit to prevent a potential learning progression effects (if a change in conative stage was observed during the protocol, the participant was excluded from the analysis); and d), the order of matches was randomly assigned. For instance, in the first middle school, a 6th grade's student practised the "SHC" task during the third lesson, then the "SFC" task during the fifth lesson and finished with the "DB" task during the seventh lesson; in the second middle school, in the class group of the same grade, a student practised the "SFC" during the third lesson, then the "DB" during the fifth lesson and finished with the "SHC" during the seventh lesson; in the third middle school, another class of 6th grade students experimented in first DB, then SHC and finally SFC. Accelerometers were worn by participants throughout each lesson and were started and finished by the teacher for all students at the same time (the time code for the start and end of the game per format was then notified by the researcher) to retrieve the data after the lessons via excel. After each format, students completed a situational interest questionnaire specific to the format they had just played, which took approximately 2 minutes to complete. To minimize socially desirable responses, students were assured that their answers would remain anonymous and confidential.

Measures

Physical activity

Actimetry was employed to objectively and non-invasively measure the average level of physical activity (PA) during participation in the different game formats. Each student wore an accelerometer positioned on the lower back, aligned with the spine, to record movement across three axes: vertical, antero-posterior, and medio-lateral. In this study, ActiGraph GT3X+ accelerometers were used due to their validated reliability in measuring PA and energy expenditure in children and adolescents. Their accuracy has been confirmed through comparisons with reference methods such as indirect calorimetry and oxygen consumption (Vanhelst et al., 2010). Prior to each data collection session, devices were inspected, initialized with ActiLife software, time-synchronized, and calibrated according to the manufacturer's instructions to ensure consistent and accurate measurements. 30 accelerometers (one for each student) were set up the day before the badminton lesson: sampling rate 100Hz, according to Orme et al. (2014). We used an epoch length of 1 second, as recommended for children's PA due to the intermittent and sporadic nature of their movements (Migueles et al., 2017). This short epoch improves the accuracy of detecting 'time spent in moderate-to-vigorous physical activity' (MVPA) (Aibar & Chanal, 2015). Cut-off points for intensity thresholds were based on data reported by Sasaki et al. (2011; Table 3). These thresholds, expressed in METs and counts, differentiated between moderate activity (45 to 103 counts per second) and vigorous activity (greater than 103 counts per second). The amount of PA was calculated using the magnitude vector (MV), derived as the square root of the sum of the squared counts recorded on each axis (X, Y, Z).

[insert Table 3]

Instant enjoyment experienced in game formats

Enjoyment during the game formats was assessed using a 19-item French Situational Interest Scale used by Roure and Pasco (2018). In this study, we focus on one of the five dimensions of this scale, instant enjoyment (IE), which has been correlated with PA levels in the literature (Ding, Sun, and Chen 2013). Participants responded to each of the three statements related to the instant enjoyment dimension on a five-point Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree). To ensure the quality of the data and the validity of the results, three exclusion criteria were applied after collecting the questionnaire responses: a) participants who left more than 20% of the items unanswered, b) participants whose answers showed no variation, and c), participants whose responses were clearly inconsistent or contradictory.

Analysis

For all quantitative variables, means and standard deviations were calculated. Categorising variables (sex, age and conative level) were described in terms of frequency and percentage. Shapiro-Wilk and Levene's tests were used to assess the normality and homoscedasticity of the data. As the data did not meet assumptions of normality and homoscedasticity, the assumptions of normality, homogeneity of variance, and independence of residuals were examined at the level of the model residuals, as recommended in the context of mixed-effects modelling (Santos Nobre and da Motta Singer, 2007). The residuals data meet the assumptions of normality and homoscedasticity, the effect of the learning design on PA and IP was assessed using a linear mixed model, with simple effects tests. In this model, PA or IE served as the dependent variable, and the learning format (DB, SHC, SFC), ability levels and sex were included as fixed effects.

Given the hierarchical structure of the data (students nested within classes and schools), linear mixed-effects models were used to check for non-independence of observations. The student and the interaction term (student × type of format design) were modelled as random effects. To quantify the extent of group-level dependency, intraclass correlation coefficients (ICC) were computed using random-intercept models with schools as clustering factors, with interpretative thresholds of ICC < 0.05 (negligible), 0.05–0.2 (low), 0.2–0.5 (moderate), and > 0.5 (high) (Koo & Li, 2016). ICC values ranged from 0.011 to 0.029, indicating that only 1.1% to 2.9% of the total variance was attributable to between-school differences, thus confirming a negligible clustering effect at the school level. This finding supports the decision to focus on within-subject analyses, given the limited number of higher-level units and the high degree of protocol standardization across schools. Post-hoc comparisons between the types of learning designs were performed, adjusting for the risk of a Type I error using the Bonferroni correction method. Two-tailed tests were used, with a statistical significance level set at 5%. Statistical analyses were conducted using R software (version 9.4). The magnitude of all significant differences was calculated using effect size (ES) estimates, following Cohen's (1988) guidelines, with η^2 values interpreted as follows: small effect for $\eta^2 > 0.01$, medium effect for $\eta^2 > 0.06$, and large effect for $\eta^2 > 0.14$.

Results

Outcomes are presented in Tables 4, 5 and 6, which show the effects of environmental and organismic constraints on PA and IE across different game formats.

Effect of environmental constraints (game format) on PA and IE

[insert Table 4]

Table 4 shows that singles formats are significantly more physically engaging than DB. In particular, PA levels were greater in singles on the full court (SFC) (103.8 ± 24.2 and a 95% confidence interval [97.9, 109.6] counts.sec^{-1}) and half-court singles (SHC) (97.4 ± 24.5 [91.2, 103.6] counts.sec^{-1}) than in DB with a large effect size (78.4 ± 22.0 [72.3, 84.5] counts.sec^{-1}) ($p < .05$; ES = .40 for SFC vs. DB, and ES = .29 for SHC vs. DB). Moreover, SHC generated less PA than SFC with a medium effect size (97.4 ± 24.5 [91.2, 103.6] counts.sec^{-1} in SHC vs. 103.8 ± 24.2 [97.9, 109.6] counts.sec^{-1} in SFC, $p < .05$, ES = .11).

Regarding IE, students reported higher levels of IE in SHC (10.5 ± 3.9 [9.2, 11.8]) compared to DB with a medium effect size (9.5 ± 4.2 [8.1, 10.9]) ($p < .05$, ES = .11). In terms of intensity, SFC is classified as a vigorous-intensity format, with PA levels averaging between 103 and 161 counts.sec^{-1}, while DB and SHC are considered moderate-intensity formats, with PA levels ranging between 45 and 103 counts.sec^{-1}.

Effect of organismic constraints (sex and skill level) on PA and IE

Positive effect of singles for all, particularly for girls…

[insert Table 5]

For girls, observed PA was greater in singles formats compared to DB. Specifically, PA was higher in SFC (95.4 ± 22.4 [90.8, 100.1] counts.sec^{-1}) and SHC (88.0 ± 20.8 [83.7, 92.4] counts.sec^{-1}) compared to DB with a large effect size (68.1 ± 20.4 [63.7, 72.2] counts.sec^{-1}) ($p < .05$, ES = .40 for SFC vs. DB, and ES = .30 for SHC vs. DB). A similar pattern was observed for boys, with PA being higher in singles formats (SFC: 111.8 ± 23.2 [106.8, 116.9] counts.sec^{-1}, SHC: 106.2 ± 24.4 [101.0, 111.4] counts.sec^{-1}) compared to DB with a large effect size (87.8 ± 19.0 [83.4, 92.3] counts.sec^{-1}) ($p < .05$, ES = .48 for SFC vs. DB, and ES = .34 for SHC vs. DB). In addition, girls reported more IE in playing SHC than DB with a medium effect size (9.9 ± 3.8 [9.3, 10.5] vs. 8.7 ± 4.0 [8.1, 9.3], $p < .05$, ES = .10). For girls, all three formats were classified as moderate-intensity activities, with PA averages remaining below 103 counts.sec^{-1} in each format. In contrast, for boys, SHC and SFC were classified as vigorous-intensity formats, while DB remained a moderate-intensity format (68.1 ± 20.4 counts.sec^{-1} < 103 counts.sec^{-1}).

… And simples are more beneficial for greater players

[insert Table 6]

The quantity of PA was significantly greater in singles formats than in DB across all skill levels. For Stage 1 (structural) players, PA was higher in singles formats (SFC: 89.5 ± 16.9 [86.1, 92.9] counts.sec^{-1}, SHC: 83.0 ± 16.3 [79.6, 86.4] counts.sec^{-1}) compared to DB with a large effect size (66.8 ± 16.9 [63.1, 70.5] counts.sec^{-1}) ($p < .05$; ES = .56 for SFC vs. DB, ES = .34 for SHC vs. DB). Similarly, for Stage 2 (functional) players, PA was greater in SFC (109.4 ± 24.3 [103.6, 115.2] counts.sec^{-1}) and SHC (102.8 ± 23.3 [97.2, 108.4] counts.sec^{-1}) than in

DB with a large effect size (81.6 ± 19.7 [76.2, 87.0] counts.sec^{-1}) ($p < .05$; ES = .47 for SFC vs. DB, ES = .37 for SHC vs. DB). For Stage 3 (technical) players, PA was again greater in SFC (123.9 ± 18.6 counts.sec^{-1} [119.3, 128.5]) and SHC (117.9 ± 23.8 [112.4, 123.4] counts.sec^{-1}) than in DB with a large effect size (97.4 ± 17.0 [93.2, 101.6] counts.sec^{-1}) ($p < .05$; ES = .57 for SFC vs. DB, ES = .44 for SHC vs. DB). Moreover, Stage 1 players displayed a significant difference between SFC and SHC with a large effect size (89.5 ± 16.9 [86.1, 92.9] counts.sec^{-1} vs. 83.0 ± 16.3 [79.6, 86.4] counts.sec^{-1}, $p < .05$, ES = .21). However, for Stage 1, all three formats resulted in moderate-intensity PA (PA < 103 counts.sec^{-1}). For Stage 2, SHC and DB were moderate-intensity formats, while SFC was a vigorous-intensity format (109.4 ± 24.3 [103.6, 115.2] counts.sec^{-1} > 103 counts.sec^{-1}). For Stage 3, both singles formats were vigorous-intensity, while DB remained a moderate-intensity format (97.4 ± 17.0 [93.2, 101.6] counts.sec^{-1} < 103 counts.sec^{-1}).

Discussion

The aim of this study was to examine the effects of different badminton game formats (SHC, SFC and DB) on student participation engagement, specifically focusing on how interaction effects between variations in the playing area and students' individual characteristics influence PA levels and participants' IE. Results indicated that SHC was perceived as equally enjoyable as SFC and more enjoyable than DB by the students. PA levels observed in the singles formats (SHC and SFC) were significantly higher than those recorded in DB. Importantly, the SFC format was the only one to meet the criteria for 'vigorous' PA intensity, highlighting its potential to effectively promote higher levels of physical engagement in students in PE.

"Playing area" effect examined critically

This study aligns with existing literature, showing that students experience high levels of IE across all the badminton formats examined (Dieu et al., 2022).

Doubles, a less promising format than half-court singles

Our results indicated that DB is perceived as less enjoyable, with a medium effect size, than SHC. This outcome supports previous evidence indicating that participation in DB does not yield a greater instant enjoyment than individual formats of badminton (Dieu et al., 2022). This result may have emerged because beginners do not have the necessary collaborative skills to take advantage of the interdependence between players that doubles play requires (Phomsoupha and Laffaye, 2015). Furthermore, this finding aligns with previous research suggesting that reduced-court formats can still provide enjoyment (Selmi et al., 2020). In terms of physical engagement, our findings confirmed that DB generates significantly less PA than SFC, consistent with previous reports from research at more competitive performance levels (Alcock and Cable, 2009). Notably, despite the smaller playing area, SHC also produces significantly higher levels of PA compared to DB, although this activity remains categorized as moderate. To optimize both IE and PA, key factors for encouraging future participation in physical activity (Lonsdale et al., 2013), our results suggest prioritizing SHC over DB.

Single on a "half" or "full" court? Quantity versus intensity of PA

Our data challenge the notion that a larger playing area inherently serves as a positive emotional inducer for all students (Visioli et al., 2024). The findings indicated that SFC is not inherently more motivating than SHC. Moreover, PA levels varied among students, with significant differences and a moderate to large effect size observed when comparing SFC to SHC. This observation aligns with research that highlights how a reduced playing area can still foster active participation in competitive team sports (*e.g.*, Clemente et al., 2017; Zouhal et al., 2020). Importantly, in accordance with data reported by Sasaki et al. (2011), SFC stands out as the only format that induced activity classified as ‘vigorous’. Extensive research underscores the advantages of vigorous-intensity exercise (Sanchez-Lastra et al., 2024). Previous literature (Bull et al., 2020) posits that two minutes of MVPA equate to one minute of vigorous-intensity exercise (VPA). The VPA generated by SFC allows students to meet the WHO's PA recommendations more efficiently. Despite its larger playing area, SFC generates comparable levels of PA to SHC. For instance, 14 students engaging in VPA during set intervals (with breaks) can achieve the same participation effects as 28 students performing MVPA continuously. Both SHC and SFC formats are promising physical activity options, with SFC emphasizing intensity and SHC prioritizing overall practice volume. By effectively balancing the quantity and intensity of PA, these formats may promote a more active lifestyle for students. Furthermore, recent evidence highlights the particular benefits of VPA for health outcomes (Sanchez-Lastra et al., 2024), supporting its promotion in PE settings. However, increasing VPA should not come at the expense of students' enjoyment, since enjoyment is a key predictor of continued participation. Moderate physical activity (MPA) has been shown to positively influence affective responses and enjoyment during exercise, which are critical for sustained motivation and adherence (Ekkekakis, 2008). Therefore, our scaling approach to playing areas in badminton supports incorporating both moderate and vigorous intensities of activity to balance health benefits with affective engagement, promoting long-term adherence to physical activity in PE.

Organismic constraints influence the interpretation of the "area" effect

While the preceding discussion focuses on the effect of different formats (environmental variable) on students, other effects are highlighted when the interaction between environmental constraints and individual constraints (students characteristics) is considered (Davids et al., 2008), such as sex differences (Table 5) or expertise (Table 6) in the analysis of formats.

Sex*area interaction

Doubles: less fun than half-court for the girls. In terms of IE, DB is less appealing than SHC, but this trend is observed only among female participants with a medium effect size. These findings challenge studies that emphasize the collective engagement aspect as a significant motivational factor for girls in PE, particularly in badminton (Bebetsos and Antoniou, 2012). Conversely, our results are consistent with prior research, which suggests that collective formats (Dieu et al., 2020a), including doubles (Dieu et al., 2022), are less enjoyable than individual game formats. As discussed in the previous section, this result may have more to do with skill level than sex differences (in our study, most of the girls were beginners). Indeed, beginners do not have the necessary collaborative skills to take advantage of the interdependence that doubles play requires (Dieu et al., 2022) resulting in a low level of enjoyment. Furthermore, these results must be viewed with caution because social relatedness and perceived competence, two variables not controlled in this study, have been observed to partly mediate the effect of cooperative games on enjoyment (Engels and Freund, 2020). Finally, these findings stand in contrast to data reported in a qualitative survey by Visioli et al. (2024) of 54 secondary students who had experienced various badminton formats, including DB, SHC and SFC. Regarding the affective dimension associated with the playing area, our results do not support the notion that a larger playing area serves as a positive emotional inducer for participation in females (Visioli et al., 2024).

Favor the half-court to optimize girls' PA. In terms of PA, our findings differ from established trends on sex differences among students. Girls exhibited MVPA levels across all formats, whereas boys demonstrated VPA during SFC and SHC. For girls, the larger playing area does not facilitate improvements in PA levels compared to the half-court format. In single-sex PE groups that exist in some French vocational secondary schools, SHC appears advantageous for optimizing girls' PA levels.

*Expertise*area interaction*

To have an impact on PA: use the half-court for novices and experts and the full court for intermediates. Consistent with existing badminton research literature, our findings show no significant differences in self-reported IE levels across formats, regardless of participant expertise. However, this trend does not extend to physical engagement (Dieu et al., 2020a; Dieu et al., 2025). Beginners (Stage 1) engaged in moderate-intensity PA across all three formats with large effect sizes, despite variations in game design. Our findings suggest that SHC is the most advantageous format for beginners, as it accommodates more participants simultaneously compared to SFC while also facilitating higher overall PA than DB. Moreover, the longitudinal scaling of the SHC format is ergonomically more suitable for students at the structural stage (beginners), who tend to prefer to play forceful returns along the central axis of the court (Dieu et al. 2020b). Intermediate-level students (stage 2), who comprised most of our sample (N=111 students, or 43%), performed at a vigorous intensity level in SFC, while maintaining moderate intensity levels in both SHC and DB. The observation of the optimization of the PA quantity/intensity ratio in game formats aligns closely with general findings for these students, allowing teachers to choose between singles formats to achieve equivalent PA engagement by adjusting either quantity (SHC) or intensity (SFC). However, at the functional stage, previous literature indicates that students prefer lateral play (Dieu et al. 2020b). Thus, it would be ergonomically beneficial to offer the SFC format, which utilizes the court's width, thereby engaging intermediate students at the level of perception and action, while enabling them to better meet PA recommendations. Finally, advanced students (Stage 3) exhibited VPA in both SFC and SHC. For advanced players, SHC is the most suitable format for maximizing PA, as it enables greater simultaneous participation in VPA. Furthermore, this longitudinally-scaled format is ergonomically tailored to advanced students in the technical stage, who favor executing depth-oriented attacking techniques (e.g., smash and drop) (Dieu et al. 2020b). Consequently, reducing the court width for experienced players fosters an active lifestyle while accommodating their specific motor skills.

Our findings highlighted the need to reevaluate badminton lesson designs. In PE typical scenarios with full classes and heterogeneous skill levels, teachers must carefully account for students' individual characteristics and needs. In such contexts, no single format may be universally ideal but teachers often rely on entrenched assumptions about the beneficial effects of organisational strategies on physical load and student motivation (Moy et al., 2016). Exploring the interaction between game format and individual constraints enables the proposal of a balanced approach, integrating both SFC and SHC elements to optimize PA during PE badminton sessions. To align more closely with WHO recommendations, which indicate that VPA can help achieve activity level targets twice as quickly as MVPA, we recommend implementing a hybrid "accordion" format. In this system, both the highest and lowest-skilled players would compete on a half-court (at their own level), while intermediate players would utilize a full court.

[insert Figure 1]

Our findings highlight the importance of adapting court size, based on student skill levels, rather than applying a universal progression model. The commonly used linear “ladder” format—where court size increases with expertise—may not be optimal for PA in all learners. Instead, a hybrid “accordion” format, which expands space for intermediate students and reduces it for both novices and experts, better accommodates diverse ability levels. This scaling approach helps maintain engagement and ensures each group operates in a space aligned with their physical and technical capabilities (known as effectivities in ecological dynamics). To implement this scaling approach effectively, teachers need a skill-level assessment tool and enough court space to adjust playing areas dynamically. Such a framework positions the teacher as an adaptive mediator, orchestrating spatial and instructional adjustments to optimize student engagement, ensure developmental appropriateness, and maintain pedagogical coherence.

Conclusion

In competitive sports, existing literature indicates that playing area dimensions significantly influence the quantity and intensity of PA (e.g., Clemente et al., 2017; Zouhal et al., 2020). However, these studies sometimes present contradictory findings, depending on whether the playing area is increased or reduced, and they often overlook the impact of individual differences among participants. In contrast, our study adopted an ecological framework, positing that the appropriate unit of analysis for understanding engagement lies at the person-environment scale of analysis transactions (Davids et al., 2008). The hybrid 'accordion' format optimizes the quantity-to-intensity ratio of PA by adapting the playing area to students' individual needs. This pedagogical strategy, integrating the benefits of half-court and full-court play is likely to promote an active lifestyle for all participants while addressing organisational constraints in PE. These findings should guide training programs for PE teachers and badminton coaches, encouraging a shift in the educator's role from a prescriber of actions to a 'designer' fostering students' physical engagement (Woods et al., 2022).

Some limitations of the study should be considered when interpreting or generalizing our findings. First, in this study, certain variables were excluded that may significantly impact PA in badminton. For example: a) although age may influence students’ engagement in physical education (Dieu et al., 2025), it did not emerge as a significant factor in the present study, possibly due to the limited representation of older students in the sample of participants. Future research with a more balanced age distribution is needed to further examine this potential effect; and b) friendship group dynamics (Zajac and Hartup, 1997) and perceived competence (Engels & Freund, 2020) can influence enjoyment in collective formats. Second, the results for confirmed students (Stage 3) should be interpreted with caution due to the small number of participants classified at this level within the school environment. Third, similar studies should be reconducted across different cultural contexts, a variable that can influence PA (Aktan et al., 2025). Replicating this study, in different school settings, with a larger sample size, (e.g. in high-school context to increase skilled participants) and considering the excluded variables (e.g. age, social relatedness and perceived competence), would be beneficial. Finally, future research should investigate longitudinal impacts of the hybrid "accordion" format on sustained PA.

Acknowledgments

This project has been carried out with the support of the X.

Disclosure statement

No potential conflict of interest was reported by the authors. The present study complies with the current laws of the country in which it was performed.

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Table 1. *Description of the sample*

Sex	N	%	Conative stage	N	%
Male	132	52,0%	1	96	37,8%
Female	122	48,0%	2	103	40,6%
			3	55	21,6%

Table 2. *The first three conative stages and their classification indicators for badminton players according to Dieu et al. (2020)*

Conative stages	Behaviour description	Classifying indicators
Stage 1: structural Conation = returning the shuttlecock	The returner. He/she returns the shuttlecock to the other side of the net regardless of where it lands.	Long rallies (7 or more hits). Long sending back-central axis. Unforced errors > forced errors. Skills based on elbow flexion without any trunk action.
Stage 2: functional Conation = directing the shuttlecock	The dispatcher. He/she seeks for free space to send the shuttlecock.	Short rallies (3-4 hits). Shuttlecock trajectories varied using the width of the court. Forced errors > unforced errors. Skills based on elbow and humeral flexion and forward-backward trunk action.
Stage 3: technical Conation = making a winning stroke	The technician. He/she seeks to smash/drop the shuttlecock but does not re-position him/herself after hitting.	Medium rallies (5-6 hits). Shuttlecock trajectories varied using the depth of the court. Forced errors = unforced errors. Skills based on upward, backswing arm action and trunk rotation.

Table 3. *VM3 cut points for different PA intensity levels (Sasaki et al. 2011)*

Activity Intensity	**MET range**	**VM3 counts.min-1**	**VM3 counts.sec-1**
Moderate	3.00-5.99	2 690-6 166	45-103
Hard	6.00-8.99	6 167-9 642	103-161
Very hard	>8.99	>9642	>161

Table 4. *Impact of game-design on PA and enjoyment*

	Type of game-design			p-value	Effect Size (ES)		
	Single full court (SFC)	Single half court (SHC)	Double (DB)		SFC vs SHC	SFC vs DB	SHC vs DB
All participants							
PA (count/sec) - mean ± EC 95%CI*	103.8 ± 24.2 [a,b] [97.9, 109.6]	97.4 ± 24.5 [c] [91.2, 103.6]	78.4 ± 22.0 [72.3, 84.5]	<.001	.11 [-.15, .37]	.40 [.12, .68]	.29 [.05, .53]
Enjoyment - mean ± EC 95%CI*	10.1 ± 4.1 [8.7, 11.5]	10.5 ± 3.9 [c] [9.2, 11.8]	9.5 ± 4.2 [8.1, 10.9]	.01	.05 [-.26, .36]	.06 [-.25, .34]	.11 [-.20, .42]

[a] significant difference between the Single full court and the Single half court match, $p < .05$.
[b] significant difference between the Single full court and the Doubles match, $p < .05$.
[c] significant difference between the Single half court and the Doubles match, $p < .05$.

Table 5. *Impact of game-design on PA level and enjoyment according to organismic constraints (gender)*

	Type of game-design			p-value	Effect Size (ES)		
	Single full court (SFC)	Single half court (SHC)	Double (DB)		SFC vs SHC	SFC vs DB	SHC vs DB
Girls							
PA (count/sec) - mean ± EC 95%CI*	95.4 ± 22.4 [a, b] [90.8, 100.1]	88.0 ± 20.8 [c] [83.7, 92.4]	68.1 ± 20.4 [63.7, 72.2]	<.001	.10 [-.20, .39]	.40 [.08, .71]	.30 [.01, .58]
Enjoyment - mean ± EC 95%CI*	9.5 ± 4.0 [8.7, 10.3]	9.9 ± 3.8 [c] [9.3, 10.5]	8.7 ± 4.0 [8.1, 9.3]	.152	.05 [-.23, .33]	.05 [-.23, .33]	.10 [-.18, .38]
Boys							
PA (count/sec) - mean ± EC 95%CI*	111.8 ± 23.2 [b] [106.8, 116.9]	106.2 ± 24.4 [c] [101.0, 111.4]	87.8 ± 19.0 [83.4, 92.3]	<.001	.14 [–.18, .46]	.48 [.19, .77]	.34 [.06, .61]
Enjoyment - mean ± EC 95%CI*	10.7 ± 4.2 [9.9, 11.5]	11.1 ± 4.0 [10.3, 11.9]	10.2 ± 4.3 [9.3, 11.0]	.08	.04 [-.27, .35]	.07 [-.20, .34]	.12 [-.15, .39]

[a] significant difference between the Single full court and the Single half court match, $p < .05$.
[b] significant difference between the Single full court and the Doubles match, $p < .05$.
[c] significant difference between the Single half court and the Doubles match, $p < .05$.
*95% CI [Lower confidence interval, Upper confidence interval]

Table 6. *Impact of game-design on PA level and enjoyment according to organismic constraints (skill level)*

	Type of game-design			p-value	Effect Size (ES)		
	Single full court (SFC)	Single half court (SHC)	Double (DB)		SFC vs SHC	SFC vs DB	SHC vs DB
Level 1 (Structural)							
PA - (mean ± EC 95%CI*)	89.5 ± 16.9 [a, b] [86.1, 92.9]	83.0 ± 16.3 [c] [79.6, 86.4]	66.8± 16.9 [63.1, 70.5]	<.001	.21 [.01, .41]	.56 [.34, .78]	.34 [.12, .56]
Enjoyment - (mean ± EC 95%CI)	9.5 ± 4.0 [8.5, 10.5]	10.2 ± 3.8 [9.2, 11.2]	9.1 ± 4.1 [8.0, 10.2]	.12	.06 [-.14, .26]	.03 [-.17, .23]	.10 [.10, .30]
Level 2 (Functional)							
PA - (mean ± EC 95%CI*)	109.4 ± 24.3 [b] [103.6, 115.2]	102.8 ± 23.3 [c] [97.2, 108.4]	81.6 ± 19.7 [76.2, 87.0]	<.001	.11 [-.09, .31]	.47 [.25, .69]	.37 [.15, .59]
Enjoyment - (mean ± EC 95%CI)	10.8 ± 4.1 [9.7, 11.9]	10.7 ± 4.1 [9.6, 11.8]	9.6 ± 4.5 [8.3, 10.9]	.06	.04 [-.16, .24]	.07 [-.13, .27]	.11 [-.09, .31]
Level 3 (Technical)							
PA - (mean ± EC 95%CI*)	123.9 ± 18.6 [b] [119.3, 128.5]	117.9 ± 23.8 [c] [112.4, 123.4]	97.4 ± 17.0 [93.2, 101.6]	<.001	.12 [-.08, .32]	.57 [.35, .79]	.44 [.22, .66]
Enjoyment - (mean ± EC 95%CI)	9.9 ± 4.2 [8.7, 11.1]	11.0 ± 4.0 [9.9, 12.1]	10.0 ± 4.1 [8.8, 11.2]	.32	.03 [-.17, .23]	.09 [-.11, .29]	.11 [-.09, .31]

[a] significant difference between the Single full court and the Single half court match, $p < .05$.
[b] significant difference between the Single full court and the Doubles match, $p < .05$.
[c] significant difference between the Single half court and the Doubles match, $p < .05$.
*95% CI [Lower confidence interval; Upper confidence interval]