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Repeatability of tidal expiratory flow limitation during peak exercise

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ABSTRACT

The presence and degree of tidal expiratory flow limitation (EFL_T) during exercise are usually determined from single observations and it is assumed that EFL_T is a repeatable phenomenon. This study aimed to determine the repeatability of the presence and degree of EFL_T and breathing patterns during peak exercise in healthy, young, athletic subjects. Fifteen subjects (9 males, 6 females; mean age of 23 ± 3 years) completed two maximal cardiopulmonary exercise tests (CPET) seven days apart. Coefficient of variation (CoV) were calculated for continuous variables and the Cohen's kappa coefficient was determined for the presence of EFL_T. There were no significant differences in CPET variables between visits. The presence or absence of EFL_T agreed in 14 out of 15 subjects (Cohen's kappa coefficient = 0.76, p = 0.007, indicating moderate agreement). The degree of EFL_T showed high variability (CoV = 32.9%). Variability was low (CoV ranged between 2.8–6.1%) for end-inspiratory lung volume, tidal volume (V_T), V_T relative to forced vital capacity, inspiratory capacity, breathing frequency, and for end-expiratory lung volume the CoV = 10.9%. In conclusion, the presence or absence of EFL_T showed good agreement and breathing patterns are highly repeatable observations in healthy subjects during peak exercise suggesting that reliable inferences can be made from single observations.

1. Introduction

Tidal expiratory flow limitation (EFL_T) occurs at a given lung volume when maximal flow is achieved and cannot be increased irrespective of increased expiratory effort. EFL_T is the consequence of ventilatory demand (determined by minute ventilation and breathing patterns) approaching and/or reaching ventilatory capacity (determined by lung volumes and expiratory flows) (Molgat-Seon, Dominelli, Peters, Kipp, Welch, Parmar, Rabbani, Mann, Grift, Guenette, & Sheel, 2022). During peak exercise, EFL_T has been linked with increased end-expiratory and end-inspiratory lung volumes, shifting the tidal breath towards total lung capacity and the steeper portion of the pressure-flow curve (Pellegrino, Brusasco, Rodarte, & Babb, 1993), greater respiratory muscle work (Dominelli, Render, Molgat-Seon, Foster, Romer, & Sheel, 2015), and exercise-induced arterial hypoxemia (Derchak, Stager, Tanner, & Chapman, 2000; Dominelli, Foster, Dominelli, Henderson, Koehle, McKenzie, & Sheel, 2013). The identification and quantification of EFL_T during exercise provides valuable information regarding mechanical ventilatory limitation during exercise for both clinical and research purposes. The presence or absence and degree of EFL_T during exercise are usually determined from a single observation and assumes that EFL_T is a repeatable phenomenon (Molgat-Seon et al., 2022).

The tidal breath overlap method is commonly used to identify and quantify EFL_T (Johnson, Weisman, Zeballos, & Beck, 1999). Briefly, the FVC loop, obtained either pre or at one-minute post exercise, is the reference flow-volume loop and is considered to represent one's maximal breathing boundary. During exercise, the tidal breaths are recorded, and an inspiratory capacity (IC) manoeuvre is performed. The IC manoeuvre is used to position the tidal breath within the FVC loop and EFL_T is inferred if the tidal breath intersects the forced vital capacity (FVC) flow-volume loop (Johnson et al, 1999). While simple and feasible, the primary limitation of this technique is concerned with accurately defining the FVC loop boundary, which may be affected by exercise-induced bronchoconstriction or bronchodilation, and thoracic gas compression (Guenette, Dominelli, Reeve, Durkin,

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Eves, & Sheel, 2010). Additionally, this method compares physiologically different flow-volume loops (i.e., tidal breath and FVC), which differ in lung mechanics, the sequential emptying of lung regions with different time-constants, and the volume and time history of lung parenchyma and airways from the preceding breath (Green & Mead, 1974). In recognition of these limitations, we developed a modification of the tidal breath overlap method using vector-based analysis (VBA), which quantifies the conformity of the tidal breath to the FVC loop (Welch, Francis, Babbage, Lardenoye, Kolbe, & Ellyett, 2021). We consider EFL_T as present when the tidal breath tracks parallel and conforms to the trajectory of the FVC loop due to the two-independent flow-volume loops experiencing the same expiratory flow-limiting conditions. The VBA method addresses many of the limitations of the tidal breath overlap method by relieving the FVC flow-volume loop of its role in determining the upper boundary for expiratory flow and rather uses the FVC flow-volume loop to establish a flow limited contour (Welch et al., 2021).

The test-retest repeatability of a limited number of cardiopulmonary exercise test (CPET) variables have been assessed in healthy subjects (Bingisser, Kaplan, Scherer, Russi, & Bloch, 1997; Covey, Larson, Alex, Wirtz, & Langbein, 1999; Decato, Bradley, Wilson, & Hegewald, 2018; Garrard & Emmons, 1986; Nordrehaug, Danielsen, Stangeland, Rosland, & Vik-Mo, 1991; Skinner, Wilmore, Jaskolska, Jaskolski, Daw, Rice, Gagnon, Wilmore, Rao, & Bouchard 1999). In a cohort of healthy subjects Decato et al (2018) reported low co-efficient of variations (CoV) at peak exercise for workload (2.7%), exercise duration (2.7%), peak oxygen uptake ($\dot{V}O_2$peak) (4.9%), minute ventilation ($\dot{V}E$peak) (7.4%), heart rate (HR) (1.8%), oxygen pulse (4.6%), and systolic (7.2%) and diastolic (10.5%) blood pressures (Decato et al, 2018). More recently, in a cohort of healthy adults, Dunsford et al (2024) found that the repeatability of EFL_T at peak exercise when expressed as a binary variable was 'minimal' (Cohen's kappa coefficient = 0.337) and 'poor' when expressed as a continuous variable (intraclass correlation coefficient = 0.338; Dunsford, Dhaliwal, Grift, Pryce, Dominelli, & Molgat-Seon, 2024). Collectively these studies suggest low variability of markers of peak exercise capacity and cardiac response; however, the test-retest repeatability of the presence or absence of EFL_T and breathing patterns is poorly understood (Molgat-Seon et al., 2022).

The primary aim of this study was to determine the repeatability of the presence and degree of EFL_T during peak exercise in healthy, young, athletic subjects. Based on the repeatability of other CPET variables, we hypothesized high repeatability of the presence or absence of EFL_T.

2. Methods

2.1. Participants

Healthy subjects aged 20–30 years who were participating in a concurrent study investigating breathing patterns during exercise were invited to participate in this test-retest repeatability study. Participants were physically fit, healthy, active, non-smokers, non-e-cigarettes users and participated in at least 4 hours of organised physical activity/sport per week. Subjects were required to have a body mass index (BMI) < 95th percentile adjusted for age. Subjects completed a screening questionnaire and were excluded if they had known respiratory, metabolic, cardiovascular, or musculoskeletal comorbidities that may limit exercise performance. Individuals receiving current inhaled therapy for asthma were excluded; however, subjects with a past diagnosis of asthma from a general practitioner based on self-reported symptoms were included.

2.2. Ethics

Institutional approval from the Auckland District Health Board research review committee (A+8144) and ethics approval from the Health and Disability Ethics Committees (18/NTB/94) were obtained. Subjects provided written informed consent.

2.3. Protocol

Subjects attended two study visits, at the same time of the day, seven days apart. Before each study visit subjects were asked to refrain from performing vigorous activity within two-days and avoid heavy meals or caffeine within two-hours prior to testing. On each occasion tests were performed in the following order: baseline spirometry, a maximal CPET, and spirometry at one-minute post-exercise. All tests were performed in in the afternoon between 4 and 7 pm, in an air-conditioned respiratory physiology laboratory 70 m above sea level. Ambient conditions were maintained at a temperature of 22 ± 1.5 degrees Celsius and 50 ± 10% humidity.

2.4. Spirometry

Spirometry was performed using a digital volume transducer turbine (Vyaire Medcial, Vyntus CPX system) in the seated position via a mouthpiece (SureGard filter, Bird Healthcare) whilst wearing a nose peg (Grip Nose Clips, Bird Healthcare) in accordance with the American Thoracic Society/European Respiratory Society guidelines (Graham, Steenbruggen, Miller, Barjaktarevic, Cooper, Hall, Hallstrand, Kaminsky, McCarthy, McCormack, Oropez, Rosenfeld, Stanojevic, Swanney, & Thompson, 2019). *Z*-scores were determined by the global lung initiative reference equations (Quanjer, Stanojevic, Cole, Baur, Hall, Culver, Enright, Hankinson, Ip, Zheng, & Stocks, 2012).

2.5. Cardiopulmonary exercise test

Subjects performed a maximal CPET to volitional exhaustion using a stepped standardised exponential exercise protocol (STEEP) on a cycle ergometer (Ergoline Via Sprint 150p) (Northridge et al., 1990). The protocol was identical for each study visit and began with a 3-minute baseline period to collect resting data (Northridge, Grant, Ford, Christie, McLenachan, Connelly, McMurray, Ray, Henderson, & Dargie, 1990). Followed by stepped stages, one-minute in duration, initially starting at a relatively low workload of two metabolic equivalents of task ($\dot{V}O_2$ = 7 $mL \cdot min^{-1} \cdot kg^{-1}$) and increasing by 15% of the previous stage every minute as determined by body weight (Northridge et al., 1990). Stepped protocols are recommended over ramped protocols when studying EFL_T as they allow the subject to establish a stable breathing pattern after each increase in workload (Johnson et al, 1999).

Breath-by-breath data were obtained by a Vyntus CPX metabolic cart (Vyaire Medical, SentrySuite software, CareFusion) via a facemask held in place by a head strap (Hans Rudolph 7450 series V2 mask) and averaged over 8 breaths. Cadence was self-selected however the CPET was stopped if the subject could not maintain a cadence of 50 rpm. Peak exercise data were averaged over the final 30 seconds of exercise.

2.6. EFL_T analysis

The FVC flow-volume loop obtained at one-minute post exercise was used for the reference loop for EFL_T analysis. IC manoeuvres were performed to determine the placement of the tidal flow-volume loop within the reference FVC loop. IC manoeuvres were practiced during baseline and were performed each minute after 80% of target heart rate was achieved: this ensured that EFL_T analysis could be performed within the last minute of exercise. The average of the ten tidal breaths prior to the IC manoeuvre were used to digitally construct the reference tidal flow-volume loop.

EFL_T was determined by the vector-based analysis technique described by Welch et al (2021). Using bespoke software developed in LabView (National Instruments, Austin Texas, USA) the flow reserve vector (FRV; measure of how close the tidal breath is to the FVC loop) and the tangential angle (quantifies the conformity of the tidal breath to the FVC loop) were determined. The VBA technique infers the presence of EFL_T as a segment of the tidal breath that demonstrates the same expiratory flow limiting conditions by conforming to the trajectory of the FVC flow-volume loop (Welch et al., 2021). The VBA technique defines the presence of EFL_T as a segment of the tidal breath where FRV is < 0.2 and tangential angle is within ± 18 degrees for ≥ 5% of the tidal breath (Welch et al., 2021). The degree of EFL_T was quantified as the percent of the tidal breath fulfilling these criteria.

2.7. Breathing patterns

The IC was subtracted from FVC to determine end-expiratory lung volume (EELV), and inspiratory reserve volume was subtracted from FVC to determine end-inspiratory lung volume (EILV). EELV and EILV were presented as a percentage of FVC.

2.8. Statistics

Subject demographics and lung function data presented as mean and standard deviation. CPET data presented as mean ± SD and range for each test. The paired Student's *t*-test compared the group means between visits. Coefficient of variation was calculated as the within-subject SD divided by the within-subject mean multiplied by 100: the group mean CoV was presented (Keteyian, Brawner, Ehrman, Ivanhoe, Boehmer, & Abraham, 2010). The Cohen's kappa coefficient was determined for the presence of EFL_T between visits. As proposed by McHugh (2012) the strength of the agreement for the Cohen's kappa coefficient were classified as: 0.00–0.20 = none; 0.21–0.39 = minimal; 0.40–0.59 = weak; 0.60–0.79 = moderate; 0.80–0.90 = strong; and > 0.91 = almost perfect (Landis & Koch, 1977; McHugh, 2012). Alpha level was set at 0.050.

3. Results

Fifteen subjects (9 males, 6 females; mean age of 23 ± 3 years; BMI of 22.9 ± 2.1) completed this study. Subjects exercised for an average of 7 (range 4–12) hours per week on 5 (range 2–7) days per week. Forced expired volume within one second (FEV_1), FVC, and FEV_1/FVC *z*-scores were within the normal range for all subjects.

The mean days between CPETs were 7 ± 1 days. All CPETs were deemed maximal as subjects achieved a respiratory exchange ratio > 1.1; > 85% maximum predicted HR; and > 85% predicted $\dot{V}O_2$peak. All subjects stated leg fatigue as the main reason for stopping the CPET. There were no statistically significant differences for any CPET variables between CPET1 and CPET2 (Table 1 and Table 2). The repeatability of markers of peak exercise capacity and cardiac response were high, with CoV ranging between 1.3–5.3% (Table 1).

During CPET1, $n = 13$ subjects demonstrated EFL_T and during CPET2 $n = 12$ of these subjects again demonstrated EFL_T (Table 2). One subject was classified as demonstrating EFL_T over 32% of the tidal breath during CPET1 but did not demonstrate EFL_T during CPET2, and two subjects did not demonstrate EFL_T at either visit. The presence or the absence of EFL_T agreed in $n = 14$ out of 15 subjects with a Cohen's kappa coefficient of 0.76 indicating 'moderate' agreement (Figure 1).

Table 1: Repeatability of markers of exercise capacity and cardiac response during peak exercise.

	CPET 1 mean ± SD (range)	CPET 2 mean ± SD (range)	CoV%	*p*
$\dot{V}O_2$peak ($mL \cdot min^{-1} \cdot kg^{-1}$)	44 ± 9 (29–56)	45 ± 9 (29–56)	2.5	0.625
Workload (Watts)	282 ± 82 (181–460)	284 ± 88 (169–460)	3.2	0.768
HR (bpm)	182 ± 10 (166–196)	181 ± 12 (160–200)	1.7	0.339
RER	1.27 ± 0.07 (1.16–1.44)	1.30 ± 0.08 (1.22–1.52)	2.7	0.064
$\dot{V}E$peak ($L \cdot min^{-1}$)	136 ± 36 (85–194)	134 ± 39 (77–206)	5.3	0.907
$\dot{V}E/VCO_2$	32 ± 4 (25–38)	31 ± 4 (24–37)	4.7	0.087
$\dot{V}E/VO_2$	41 ± 5 (30–50)	40 ± 6 (32–50)	4.5	0.511
$PetCO_2$ (kPa)	4.7 ± 0.6 (3.8–5.9)	4.8 ± 0.7 (4.0–5.9)	3.6	0.078
$PetO_2$ (kPa)	15.9 ± 0.6 (14.8–16.9)	15.9 ± 0.7 (14.9–17.0)	1.3	0.793
O_2 pulse ($mL \cdot beat$)	17 ± 5 (12–27)	18 ± 5 (12–28)	2.2	0.190

Note: $\dot{V}O_2$peak, peak oxygen uptake; HR, heart rate; RER, respiratory exchange ratio; $\dot{V}E$peak, minute ventilation; $\dot{V}E/VCO_2$, ventilatory equivalent for CO_2; $\dot{V}E/VO_2$, ventilatory equivalent for O_2; $PetCO_2$, end tidal partial pressure of carbon dioxide; $PetO_2$, end tidal partial pressure of oxygen.

Table 2: Repeatability of ventilatory response during peak exercise.

	CPET 1 mean ± SD (range)	CPET 2 mean ± SD (range)	CoV%	*p*
EFL_T (%V_T)	31 ± 23 (0–69)	35 ± 28 (0–72)	32.9	0.464
EELV (% FVC)	26 ± 6 (18–38)	27 ± 6 (16–37)	10.9	0.407
EILV (% FVC)	83 ± 6 (71–95)	84 ± 6 (72–92)	2.8	0.161
V_T/FVC (%)	57 ± 6 (46–68)	58 ± 9 (45–73)	5.5	0.572
IC (L)	3.6 ± 0.6 (2.8–4.4)	3.5 ± 0.6 (2.7–4.2)	3.7	0.108
V_T (L)	2.8 ± 0.7 (1.7–4.1)	2.7 ± 0.6 (1.6–3.6)	4.5	0.228
RR ($1 \cdot min^{-1}$)	48 ± 10 (27–67)	48 ± 10 (28–64)	6.1	0.608

Note: EFL_T (%V_T), degree of tidal expiratory flow limitation as a percent of tidal volume; EELV (%FVC), end expiratory lung volume as a percent of forced vital capacity; EILV (%FVC), end inspiratory lung volume as a percent of forced vital capacity; V_T/FVC, tidal volume as a percent of forced vital capacity; IC, inspiratory capacity; V_T, tidal volume; RR, respiratory rate.

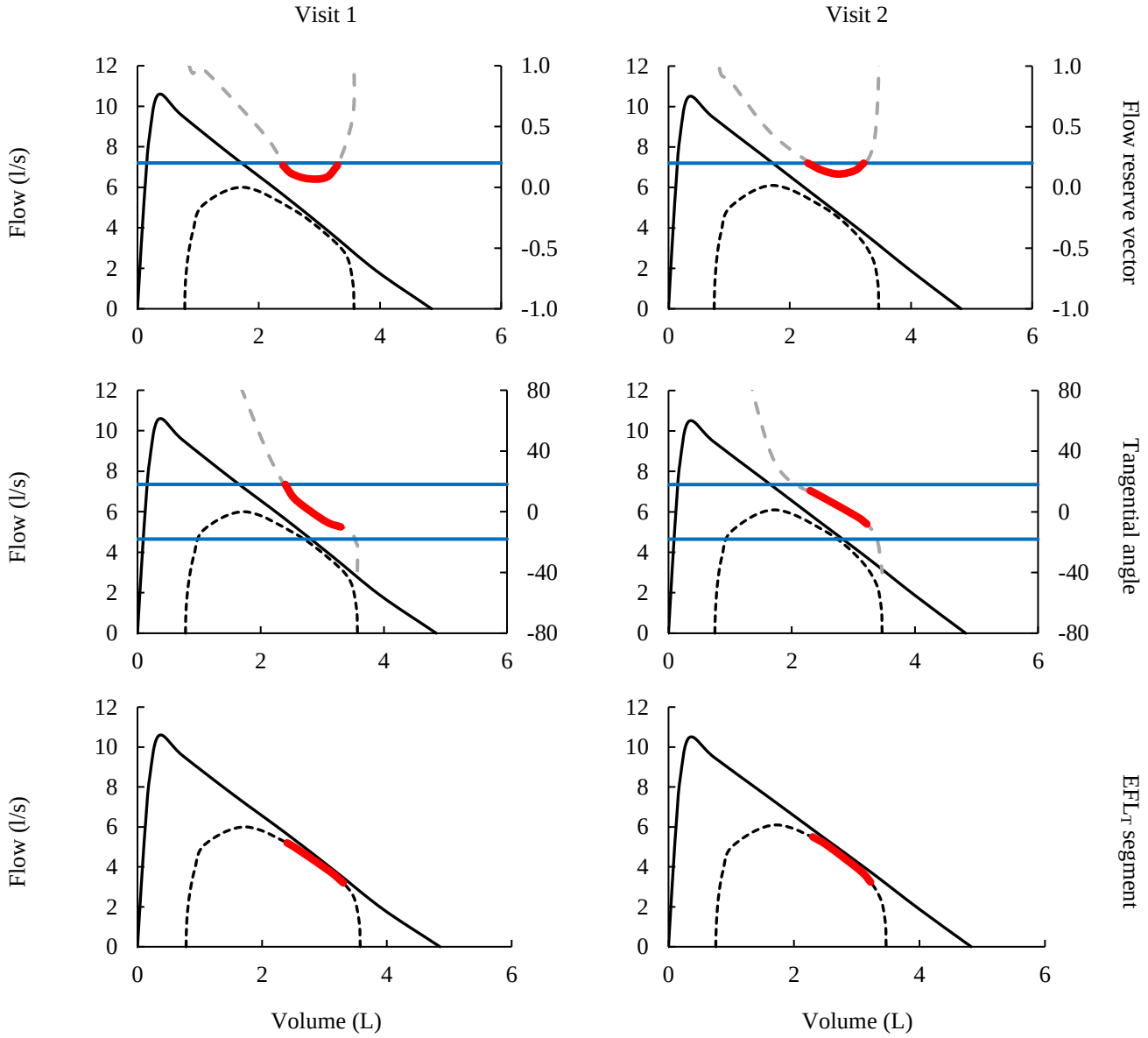

Figure 1: Expiratory flow limited segment. The figures plot the group average FVC loop (solid black line) and peak exercise tidal breath (black dotted line) for visit 1 (left column) and visit 2 (right column). The thick red in each figure indicates the proportion of the tidal breath that is classified as demonstrating EFL_T using our vector-based analysis technique (i.e., FRV < 0.2 and tangential angle within ± 18°).

On average, there was no difference in the degree of EFL_T between CPET1 and CPET 2 (33 ± 23 vs 35 ± 28 % of V_T, p = 0.572) (Table 2 and Figure 2). The CoV for the degree of EFL_T was 32.9%. The CoV were low and ranged between (2.8–6.1%) for EILV, IC, V_T, V_T/FVC and respiratory rate, and the CoV was higher for EELV (10.9%) (Table 2).

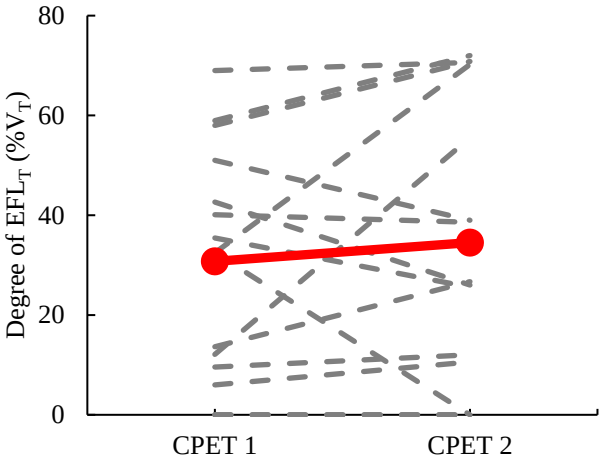

Figure 2: Degree of EFL_T. *Note:* This figure illustrates the high within subject variability of the degree of EFL_T between CPET 1 and CPET 2. The grey dashed lines represent individual subjects, and the thick red line is the group mean.

4. Discussion

This study describes the test-retest repeatability of the presence and degree of EFL_T and breathing patterns during peak exercise in healthy, athletic subjects exercising on a cycle ergometer. There were no significant differences in CPET variables between study visits which suggests that no learning or training effect occurred between visits. The main finding was that the agreement of the presence (or absence) of EFL_T during peak exercise was 'moderate' when treated as a binary variable but when treated as a continuous variable (i.e., the degree of EFL_T) the variability was high. Furthermore, we generally found low between visit variability for markers of breathing patterns during peak exercise.

Establishing the repeatability of CPET variables is important when comparing measures at different times; for monitoring disease progression or determining the response to treatment or an exercise training program. Additionally, establishing the test-retest repeatability of the presence (or absence) of EFL_T during exercise provides confidence of its presence when observed in a single diagnostic test. Like DeCato et al. (2018) we found higher repeatability than previously reported for markers of exercise capacity and cardiac response (Decato et al, 2018). In contrast to Dunsford et al. (2024) our study found that the presence of EFL_T, when expressed as a binary variable, is a highly repeatable phenomenon in healthy subjects during peak exercise (Dunsford et al., 2024). In keeping with Dunsford et al. (2024), when expressing EFL_T as a continuous variable to assess the degree of EFL_T, high variability was observed (CoV = 32.9%) which contrasts with other CPET parameters and routine respiratory measures such as FVC, FEV_1, and diffusion capacity of the lungs for carbon monoxide which have reported CoV < 4% in healthy subjects (Becker, Blonshine, Bialek, Moran, & Blonshine, 2022; Punjabi, Shade, Patel, & Wise, 2003). The difference in findings of the presence (or absence) of EFL_T at peak exercise between our study and Dunsford et al. (2024) likely reflects the smaller sample size of our cohort and the method used to determine EFL_T. Our sample size was relatively small, and most subjects demonstrated EFL_T which by chance may have reduced the variability in our cohort and partly explain the higher Cohen's kappa coefficient found in our study. We determined the degree of EFL_T using a vector-based analysis technique which quantifies the conformity of the tidal breath to the FVC loop whereas Dunsford et al. (2024) used the tidal breath overlap method (Welch et al., 2021). As summarised by Haverkamp et al. (2025) in a recent review, the tidal breath overlap method has many limitations which may over- or under- estimate the presence and degree of EFL_T (Haverkamp, Petrics, & Molgat-Seon, 2025). The VBA technique used in our study assumes that when the tidal breath tracks parallel to the FVC loop that both these independent flow-volume loops are demonstrating the same flow-limiting conditions which addresses many of the limitations of the tidal breath overlap method (Welch et al., 2021). Due to the limitations of quantifying the degree of EFL_T (Johnson et al, 1999), many authors opt to report EFL_T as a binary and not a continuous variable (Molgat-Seon et al., 2022).

The repeatability of the breathing patterns during peak exercise in healthy subjects has received little attention. $\dot{V}E$peak is the most reported ventilatory variable with CoV ranging between 7–28% (Bingisser et al, 1997; Decato et al, 2018; Garrard & Emmons, 1986; Nordrehaug et al, 1991; Skinner et al., 1999). Our study found a lower than previously reported CoV for $\dot{V}E$peak (5.3%). Furthermore, we reported low CoV (< 7%) for respiratory rate, V_T, EILV, IC and V_T/FVC, and a slightly higher CoV of 10.9% for EELV. These data suggest low variability of breathing patterns in healthy subjects during peak exercise on a cycle ergometer, which is in keeping with the findings of Dunsford et al. (2024). Furthermore, our results support the findings of Hedge et al. (2022) who used respiratory inductance plethysmography and showed that the thoracic-abdominal compartmental contributions to V_T are repeatable during heavy exercise on a cycle ergometer (Hedge, Hughson, & Dominelli, 2022).

There are several limitations of our study that should be acknowledged. Although consistent with other studies assessing the repeatability of CPET parameters in healthy subjects (Bingisser et al, 1997; Covey et al, 1999; Garrard & Emmons, 1986; Nordrehaug et al, 1991) our study had a low sample size. The low number of female participants meant that we could not assess sex-based differences, however there is no indication in the literature or from a physiological basis that sex would be a cofounding factor in the repeatability of ventilatory response during exercise. Self-selection bias may have occurred as our inclusion criteria likely attracted highly motivated and physically fit subjects more likely to give maximal effort during each CPET. Our study used the cycle ergometer; it is unknown if exercise modality influences the repeatability of the ventilatory response at peak exercise. The repeatability of ventilatory patterns and constraints at peak exercise should also be established for the treadmill: the treadmill and cycle ergometer are commonly used exercise modalities both clinically and for research. The STEEP protocol was used for this study; it is possible that the exercise

protocol may have influenced the presence and degree of EFL_T. However, given our study analysed the presence and degree of EFL_T at peak exercise, assuming different exercise protocols result in a maximal test, it is unlikely that the exercise profile leading to the achievement of peak exercise influenced our findings.

Due to these points, our findings are representative of a young, athletic population and may not be generalizable to non-athletic, older, or chronically ill subjects, or different exercise modalities. Future studies should focus on clinical populations, children, older adults and use other CPET protocol such as a standardised ramp test.

In conclusion, in healthy subjects exercising on a cycle ergometer this study showed that the presence of EFL_T and breathing patterns are repeatable during peak exercise however the degree of EFL_T is variable. This study suggests that in young healthy subjects exercising on a cycle ergometer, reliable inferences regarding the presence of EFL_T and breathing patterns can be made from single observations.

Conflict of Interest

The authors declare no conflict of interests.

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Self-identified and observed coaching styles of Australian junior community cricket coaches

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ABSTRACT

This paper addresses the question: Were the observed coaching styles of community cricket coaches in alignment with their self-reported use of coaching styles of the Game Sense approach (GSA)? Coaches practice was observed and analysed using the Spectrum of Coaching Styles (Pill et al., 2022). Five styles were observed: Coaching by Task – Style B, Individual Programming – Style D, Guided Discovery – Style F, Problem Solving – Style G and Creativity – Style H. In the Spectrum of Coaching Styles, Style B and D are regarded as coaching for reproduction of the knowledge, skills and understanding described and prescribed by the coach, whilst Style F, G and H necessitate participants to solve problems created by the coach and they are the styles most often associated with a GSA. The coaches self-identified coaching practice as a GSA did not align with the observed coaching styles during this study. Contextual to this study, Cricket Australia's (CA) principles of coaching espouse principles associated with a game-based approach such as the GSA. The ideas coaches espoused regarding their coaching and their observed coaching suggests improved pedagogical knowledge is required.

1. Introduction

This project investigated junior community cricket coaches coaching styles. In this paper, coaching styles is synonymous with pedagogies which some may also call instructional strategies (Hewitt et al. 2016). Community cricket coaches are usually (if not always) volunteers who receive no renumeration for their time and effort and voluntarily participate in introductory and more advanced coaching accreditation courses (Pill et al., 2022). As the governing body of cricket in Australia, Cricket Australia (CA) provides free online courses for coaches (Cricket Australia, 2022a). CA's principles of coaching espouses a pedagogical expression recognisable as a game-based approach (GBA) (Cricket Australia, 2022b); however, unlike some other sports (like Australian football/AFL) there is no requirement for community coaches to have completed coaching accreditation to coach junior cricket at community clubs.

CA's junior coaching framework emphasises player problem solving and playing games (Cricket Australia, 2022b). Since 1996, the Game Sense approach (GSA) has been promoted by the Australian Sport Commission (ASC) as the GBA to coaching junior sport (Australian Sport Commission, 1996; 2023). In contrast to directive instruction for specific reproduction of coach prescribed movement explanations and demonstrations, a GSA requires a coach to use questioning strategies in preference to direct instruction (Australian Sport Commission, 1996) to position the player as an active constructor of their understanding (i.e., the coach developing thinking players; den Duyn, 1997). Aligned with the key precepts of a GSA as a GBA emphasising coach use of questions to engage players cognitive construction of understanding, CA suggests the use of a coaching approach that fosters player problem solving and game form practice, and suggests this approach is motivational to young players continued participation (Cricket Australia, 2022b).

Some have suggested that a GSA is frequently misunderstood by coaches or remains an innovation to most (Pill, 2021). Coaches observed coaching styles during practice sessions have been found in some sports to not match their intention to be game-based coaches (Hewitt et al., 2016). Coaches may attempt to create game-like practice scenarios but have been found to fail to

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position the player as actively thinking about the game as the coach is using directive pedagogy (Light, 2012) whereby the coach tells the player 'what' to do, 'how' to do it' and 'when' to do it, which may be called Coaching by Task or practice style pedagogy (Pill et al., 2022). In this study, we refer to a coaching style as those identified in The Spectrum of Coaching Styles section that follows. Research with junior cricket coaches found another GBA, Teaching Games for Understanding (Bunker & Thorpe, 1982), challenging, particularly the use of questioning strategies. The research reasoned that this may be a consequence of insufficient pedagogical content knowledge and the inability to access appropriate support material (Roberts, 2011). Impacting coaches understanding of a GBA, Culver et al. (2019) research on coach education found coach educators design courses emphasising learner centred approaches to be used to coach participants but lack the knowledge to design for learner-centred approaches themselves. Furthermore, both coach developers and coaches found a constructivist approach to learning too different to the traditional lecture format of learning.

1.1. Game Based Coaching

Cricket coaches may struggle with the identification and implementation of coaching styles that reflect CA's goals of practice as problem solving in game-like practice. Australian community cricket training has recently been reported as consisting of training practices that are 'outdated, restrictive and monotonous' (Lascu et al., 2021, p. 1), and that attempts to use GBAs so practice can more closely resemble the requirements of the game of cricket have proven difficult for cricket coaches (Lascu at al., 2020b). This suggests little has changed since Low et al. (2013) found players spending most of their time in training form or drill like activities typical of common 'net' practice sessions, rather than in playing form or game-like activities. Low and colleagues suggested that players participating in drill like activities typical of common 'net' practice sessions were therefore being perceptually, cognitively and motor skill underdeveloped due to the lack of representativeness of practice to the game. Exemplifying this idea about net sessions, Lascu et al. (2020a) showed that in net sessions, batters had little opportunity to view consequences of bat-ball contact or shot selection as would occur in a game, and bowlers frequently did not get the opportunity to bowl 6 balls in a row or practice manipulating the batter as would happen in a game. Lascu et al. (2021) suggested the need for coach development focused practice that represented to players the demands of the game (i.e., representative learning). To date, little research has examined the impact of game-like or representative designs of cricket training environments.

Representative learning requires practice based on realistic learning contexts that simulate the demands of the performance environment (O'Connor et al., 2020; Hodges & Lohse, 2022), or in other words, provide representation of the action logic (Gréhaigne, Godbout, & Bouthier, 1999) of the play. In the context of cricket, a representation of the action logic would require the same movements (i.e., shot play) and decision-making processes (i.e., hitting away from the fielders, deciding when to run) that would occur during match play, and achieved by simulating the key sources of information available to the players (i.e., where the ball is bowled, where fielders are standing). To this end, Vickery et al. (2013) trialled a small-sided game format called 'Battlezone' concluding that it provided suitable training replication of the physiological, physical and technical demands of one-day cricket. Connor et al. (2016) and Connor et al. (2018) used representative training scenarios with professional, amateur and junior level cricketeers to assess the emergence of skilled batting over a 12-week period. Batters were given a scenario (e.g., score as many runs as possible without being dismissed) and mannequins were placed on the field to create an environment requiring players to hit to places where fielders are not. This external outcome focus of players resulted in improved run scoring ability, bat-ball contact, and technical efficiency (Connor et al., 2018).

1.2. Player retention

A premise of this research is that 'good coaching' is imperative to player learning and retention (Agnew & Pill, 2023). It is argued good coaching entails creating practice tasks which are congruent with the needs of the player as a learner (Pill et al., 2021) to 'connect learners in consequential goal-orientated activities with the aim of achieving instructional outcomes specific to an individual lesson or group of lessons' (Hewitt et al. 2017, p. 1). Further to this, we suggest good cricket coaching would align with CA's goals of creating environments which foster problem solving in game like environments or game forms.

1.3. The Spectrum of Coaching Styles

This study used The Spectrum of Coaching Styles (The Spectrum: Table 1) to assess coaches observed coaching behaviour. The Spectrum is an adaptation of The Spectrum of Teaching Styles to sport coaching (Pill et al., 2022). Here, coaching styles is synonymous with teaching styles in the belief that the sport coach is an educator (Jones, 2006). The Spectrum contains two clusters of coaching styles, the Reproduction cluster where the coaching style requires the player/s to reproduce requirements prescribed by the coach, and the Production cluster where players have greater ownership for thinking and enacting practice as independent or self -regulated learners. The Spectrum has been used in Australian sport coaching research by others to observe coaches and their coaching styles used during practice sessions with players (e.g., Hewitt et al., 2016; Pill et al., 2016) and with physical education teachers (Cothran et al., 2005; SueSee et al., 2018; SueSee & Barker, 2019) recording self-reported teaching styles. The studies of The Spectrum with sport coaches report that coaches predominantly use Coaching by Task – Practice Style B from The Spectrum, despite coaches self-reporting that they use a range of styles congruent with the ASC advice to be game-based in their coaching. Reasons given for the lack of congruence were coaches lack of understanding of GBA teaching/coaching styles, lack of coach development support in GBA's and the influence of previous experiences. Researchers (Hewitt, 2015; Pill et al., 2022) suggested that The Spectrum could assist improving alignment between the coaching styles used by coaches and with that desired by relevant bodies for junior coaching to be game-based by identifying 'how and what learning the coach pedagogy facilitates during practice sessions and enable dialogue with coaches about the application of teaching styles during practice sessions for purposeful outcomes' (Pill et al., 2022, p. 143).

Table 1: Spectrum of Coaching Styles (Pill et al., 2022).

Coaching Style	Description
Coaching by Command: Style A	The coach selects the task that the player/s perform in a unison, choreographed or precision performance image following the exact pacing and rhythm (cues) set by the coach.
Coaching by Task (Practice) Style B	The coach selects the subject matter tasks, the quantity, and the time limits so that player/s can practice individually and privately. The coach circulates among all player/s and offers private feedback. The player/s learn to set a pace to practice tasks within an allocated time frame.
Reciprocal Coaching (Peer Coaching): Style C	The coach selects the subject matter tasks and presents the expectations for player/s to work with a partner. One player (the doer) practices the task, while the other player (the observer) uses coach prepared criteria (checklist) to offer immediate feedback about the performance to the doer. When the first set of tasks are finished, the players switch roles and continue to the second set of tasks. The coach interacts with the observer to affirm the use of the criteria and the accuracy of the feedback comments and/or to redirects the observer's focus to specific performance details on the criteria.
Coaching by Individual Programming (Self-Check): Style D	The coach selects the subject matter tasks and designs the criteria (performance checklist) for player/s. Player/s individually practice the tasks and check their own performance using the checklist. The coach privately communicates with player/s to listen to their self-assessment comments and either reinforces the player's use of the criteria or redirects the player's focus to specific performance details on the criteria.
Small Group Coaching (Inclusion): Style E	The coach selects the subject matter tasks and designs multiple levels of difficulty for each task. Player/s select the level of difficulty that is appropriate to their performance. If inappropriate level decisions are made, the player may change the level choice. Players check their performance using the coach prepared performance checklist (criteria sheet). The coach circulates to acknowledge the choices the players have made and to ask questions for clarification to affirm the accuracy of the player's assessment process and/or to redirect the learner's focus to specific performance details on the criteria.
Coaching by Guided Discovery: Style F	The coach asks one player a series of specific questions; each question has only one correct answer. The questions are sequenced in a logical pattern so that each answer leads the player step by step to discover the anticipated concept, principle, relationship or solution.
Coaching by Problem Solving (Convergent Discovery): Style G	The coach designs a situation or one question that has only one specific correct response—the situation or question is new, and the response is not previously known to the player/s. The players are given individual and private time to use their thinking and questioning skills to sequentially and logically discover the anticipated answer.
Coaching for Creativity (Divergent Discovery): Style H	The coach designs a single or series of problems, situations or questions that seek multiple solutions to the same problem. The task is new to the player/s; therefore, each player is invited to discover new possibilities, as they produce multiple responses to the specific problem. The coach acknowledges the production of multiple ideas, rather than any singular idea.
Player Designed—Coach Supported: Style I	The coach designates a broad subject matter/topic. Within that topic each player is responsible for producing an individual learning program that includes setting goals and the process for accomplishing the goals. The player/s design, implement, refine the program, and create performance criteria for their individual learning programs. The coach acknowledges the production of ideas and asks questions for information or clarification about the learning program.
Player Initiated—Coach Supported: Style J	A player initiates a request to the coach to plan his/her own learning experience. In this experience the player makes all the decisions: selects the subject matter intent, designs, executes, and identifies the assessment criteria for the learning experience. The coach participates when and how the player requests. The coach acknowledges the learner's successful implementation of the plans and initiates questions where discrepancies emerge between the learner's intent and actions. It is not the coach's job to evaluate, rather to act as a reference source between the indicated intent and action when asked by the player.
Player Self-Coaching: Style K	The learner takes the role of both student and coach setting all learning objectives. The learner makes decisions about subject matter intent, design, execution, and assessment of the learning experiences. This style is independent of a coach and not initiated by a coach. Feedback from others occurs only IF the learner seeks it.

In our study, The Spectrum was used to view the coaching practices as it provided a common pedagogical language for coaching styles and helped give the behaviours and deliberate decisions of the coach and players clarity (Pill et al., 2022). It did this by describing 'who is doing what' and what the cognitive intentions or behaviours are of both the players and coach during the observed practice session.

This paper makes a distinctive contribution to the literature by developing understanding of the congruence between the everyday pedagogical endeavour (Jones, 2007) of the community sport coach and this alignment with advocacy of a GBA by the national body of the sport. It also highlights the need to question the likelihood of coaches using GBA's if the content of coaching courses does not reflect these coaching styles and on-going coach development in a GBA is not available to the coaches.

2. Methods

The paper aimed to address the research question - Were the observed coaching styles of community cricket coaches in alignment with the coaches self-reported belief about their use of coaching styles? This investigation used a mixed methods approach to collect data. Three 1-hour interviews were used to generate data about how often a sample of community cricket coaches reported using coaching styles to coach their participants. Coding of three 1-hour coaching sessions (three coaches times three 1-hour sessions $n = 9$ sessions) was used for the second part of the investigation. The value of observational research of coaches practice sessions to enrich our understanding of the coaching process and to identify the teaching styles of coaches within practice environments have been demonstrated by others (Potrac et al., 2000; Hewitt et al., 2016). The use of observation has been acknowledged as a valuable tool for delivering quantitative descriptions of coaching behaviour (Darst et al., 1989; DeMarco et al., 1996) as observation can provide data of demonstrated coaching styles in the authentic or 'natural' coaching environment.

2.1. Participants and setting

2.1.1. Ethics

The research project followed the ethical guidelines outlined by the University of Southern Queensland and ethics approval code H21REA162. Consent for the research was obtained from the participants. Any player who did not wish to be filmed was not filmed. Confidentiality was assured to all participants with anonymity guaranteed. All videos are stored on a password-protected computer and deleted after the coding were completed for the second time.

Coaches from a community cricket club in a large Australian city were sent an email from the club president asking if any were interested in being participants in a study titled 'Making Net Sessions more game-like'. Convenience sampling was used, and numerous coaches ($n = 9$) expressed interest, and three coaches were purposively selected from the initial group to represent a range of variables including age of participants being coached, years coaching and ability level, and the time available for the study. The three coaches chosen represented novice, intermediate and experienced and the age groups coached included u/12 club team, u/16 representative team and u/17 club team. This sample represented a range of player abilities, range of reasons for coaching (competitive, representative and social) and a range of experience (in terms of years and qualifications) with coaching. Participant 1 was a Level 1 coach, Participant 2, a Level 2 Coach and Participant 3 a Level 3 coach. A Level 1 qualification (or Junior Cricket Course) prepares the coach for junior coaching at a community or club level, whilst a Level 2 course is Representative Coaching for representative teams (such as state team). The Level 3 course, or High-Performance Coach is an invitation only course for aspiring high-performance coaches. The participants self-identified as interested and were 'biased' towards making net sessions more game-like and working to improve their coaching.

2.2. Data collection

The mixed methods approach used interviews to establish the self-reported styles of the coach and observations being analysed to determine congruence of the self-reported coaching styles and the coach's observed coaching styles. All interviews and coaching sessions were video recorded with a GoPro digital video camera. For the interviews the camera was placed on a surface and the conversation was recorded along with the dictation function on the researcher's computer. For the three 1-hour coaching sessions a chest strap was attached to the GoPro and the participants wore the camera. This method of recording proved sufficient for the coding process. The GoPro worn by the coach showed the coach's view of the coaching sessions. The researcher was positioned approximately five metres from the coach during most of the session. All video recording began with the first instruction by the coach about the session activities and purpose. These procedures have been used by others (SueSee & Barker, 2019; Hewitt et al., 2016) to observe teaching styles in physical education and coaching.

2.3. Procedure

Interview: The 1-hour interviews recorded the three coach's beliefs about their coaching styles and were done after three 1-hour coaching sessions (9 sessions in total) were completed and recorded. Firstly, participants were asked questions to confirm their coaching experience, qualifications, age group and level or grade. The participants were asked to describe their coaching philosophy in terms of what they were trying to achieve, how they would achieve these goals and to describe examples of what a session looks like, and what are the players doing? The three 1-hour coaching sessions that were completed before the interviews were used as scenarios to ask the participants what they were doing in specific situations and to confirm if these were 'usual' coaching sessions for them. In comparison to others (Hewitt et al., 2016; SueSee & Barker, 2019) who have used a specific Spectrum questionnaire, the researchers decided not to use The Spectrum specific coaching styles definitions during the interviews for two reasons. Firstly, the researchers did not wish to influence the participants answers in any way by suggesting specific styles. The second reason was the researchers did not wish to create confusion as the participants potentially did not know specific coaching

styles. The participants did know that the title of the research project was 'Making Net Sessions more game-like' and that the purpose of this pilot was to establish a baseline of their coaching styles. Interviews were chosen as a method of data collection based on the research question and as the researchers was attempting to establish the coaching styles community cricket coaches identified using and the coaching styles they were observed using. Therefore, the interviews were not analysed, or themes identified. The responses to what the coaches said were recorded and accepted. If the researchers were unsure of answers or required more information for clarification, they would ask the participants to elaborate or explain in more detail.

Observation: Observations of a coach's practice session can be a means through which to understand a coach's coaching process and to identify the coaching style of the coach (Hewitt et al., 2016; Potrac et al., 2000). Observation assessment is acknowledged as a method providing quantitative descriptions of coaching behaviour (Hewitt et al., 2016). Observation provides baseline data of actual (demonstrated in the coaching environment) instructional strategies used by the coach, which provides insights into their coaching style. We acknowledge that observational tools can only measure what the tool is designed to 'see' (Hewitt et al., 2016). Observational research was used to collect the data to establish the coaching styles used by the coaches.

2.4. Data analysis

Nine coaching sessions (three sessions per participant) were video recorded with the coaches wearing a GoPro so that instructions and images were collected. Two coders were used. Both coders had extensive knowledge of The Spectrum with regards to The Spectrum styles and both have extensive experience coding Physical Education Teachers. The researchers used The Spectrum styles to define 11 coaching styles (Table 1).

2.5. Coding instruments and procedures

Previous studies (Cothran et. al., 2005; Hewitt & Edwards, 2015; Hewitt et al., 2016; SueSee et al., 2019; SueSee & Barker, 2019) recorded teacher self-reported teaching (physical education) styles, sport coaching styles and the observed teaching (physical education) and coaching (sport) styles used. In this case the researchers were attempting to observe the coaching behaviour of community cricket coaches and record if this aligned to their self-reported beliefs regarding their coaching styles. The video recordings of sessions were reviewed and coded using four tools: (1) Ashworth's (2002) Identification of Classroom Teaching Learning Styles (see also Hewitt & Edwards, 2011; SueSee, 2012); (2) the Identification of Classroom Teaching Learning Style (Byra et al., 2014; Hewitt et al., 2016; SueSee & Edwards, 2011); (3) Sherman's (1982) Style analysis checklist for Mosston and Ashworth's spectrum of teaching styles (Byra et al., 2014); and (4) the Style analysis checklists for Mosston's spectrum of teaching styles (Sherman, 1982).

Two coders used terminology from The Spectrum of Coaching Styles (Pill et al., 2022) as a basis to identify the observed styles being used by the coaches. Coding involved using the Instrument for Identifying Coding Sheet (IFITS), which involved a ten second observation followed by a ten second recording of this observation (i.e., a decision every 20 seconds). The decisions the coders were making involved determining which coaching style was being used in the previous ten second period. This process has successfully been used by others using The Spectrum to code coaching behaviour and teaching behaviour (SueSee et al., 2019; SueSee & Barker, 2019; Hewitt et al., 2016) and the use of a similar protocol allows comparison between research with similar methods. The coders used the four tools to make the decision (based on the coaches' and students' behaviour) about which coaching style was being used. Where two or more coaching styles were employed in a period of observation, the style would be coded as the style closest to the production end of the Spectrum. Research by others (SueSee & Barker, 2019; Hewitt et al., 2016) have coded in the same manner when observing physical education teachers and tennis coaches. The application of this procedure allows comparison between this research and others. Reliability of coding is important when decisions are being made based on observations. Inter-observer reliability was calculated using the formula:

$$\text{Inter-observer agreement} = \frac{\text{Agreements}}{(\text{Agreements} + \text{Disagreements})} \times 100$$

By using this formula, inter-observer agreement was calculated across the six observed sessions using the three tools and coding sheet. 100% agreement was the highest agreement recorded; the lowest was 94.8%. Researchers have suggested that 85% or higher needs to be achieved to be considered an appropriate level of reliability (Rushall, 1977; van der Mars, 1989).

3. Results

Participant One's coaching philosophy indicated a desire to improve both physical and social skills:

> I suppose my coaching philosophy is around fun and getting them engaged with the game so they come back again next year… yeah making them that little bit better than the year before and making them better human beings than teammates.

He suggested he achieved that through:

> …a lot of game play around where we discuss the scenarios if we set a challenge of a certain amount of runs to score or do we take the run or where do we throw the ball shouldn't we be back up all of that will be discussed at the time yeah so that people get a better picture of what we are trying to achieve.

Participant Two suggested:

> I want to see the kids improve with me it is trying to work on their strengths rather than their weaknesses.

Participant Two suggested the players he was coaching (15 years of age) were at a level of ability that further improvement was not required:

> …with the 15-year olds you're a batsman and we will focus on you as a batsman. I don't need you bowling in again because we've got plenty of other kids to bowl so therefore you don't have to practice bowling. We're not going to pick up on your technical abilities with bowling unless we see

> something. You'll always be a bowler; you're just a hack as a batsman sort of thing so… and I try to do that in the games as well.

Participant Two appeared quite traditional (Low et al., 2013) in the ways they tried to develop teamwork when fielding:

> …we work as a unit when fielding and they suffer the consequences of fielding as a unit. So now it's when they drop a catch in the catching drills everybody does five pushups not just one person drops the catch everyone does it and it's amazing how the focus and the distractions disappear when they work as a team when they're all suffering together.

Participant Two valued the incorporation of competition into drills and was very positive towards net sessions:

> I think the nets are fantastic in the way of if I can do one on one with the batsman. I will get them working on their footwork, not necessarily their technique, it doesn't matter. It's all about footwork and body position for me. …The volume is the key thing right. Like I (don't) have a pop-up net and a pop-up cricket net where I can set up on a centre wicket and (also) we just haven't got the time to set that up.

Conversely, Participant Two did not believe net sessions were great for bowlers, attributing this belief to something he read:

> …because they're intimidated by the claustrophobic feel of it—particularly spinners…I read a book by Ashley Mallet on Clary Grimmet, Australian leg spinner. He refused to bowl to batsman in the nets because it never replicated a match situation, because batsman in the nets have more bravado, no repercussions, just whacking the ball, so therefore they never played him properly as if they were out in the centre wicket.

Participant Three's philosophy was specific about his goals with an emphasis on cognition, reflection and learning.

> …the one underlying theme or philosophy is that you know the best coach you need or are going to ever have is the one that's inside your head. It's about them being able to be reflective and thinking cricketers and that's probably more the goal of everything I try and do is that you know provide an environment that's safe and supportive but allow them to challenge themselves with their learning regarding cricket so being reflective.

Participant Three emphasised the need for player autonomy. When they were asked to elaborate on how they developed these reflective and thinking cricketers Participant Three suggested:

> …setting up new environment for your group of kids and really, it's doing that… setting it up and getting out of the way and letting you know I try to let the players run both the drills and the scenarios themselves….so really, it's setting up the scenario or the drill he's still being clear with the constraints and then getting out of the way and letting it unfold and then jumping in for you know when there's those teachable moments or they reflective questions and try and get them to debrief it at the end.

To summarise, Participant One suggested they used a lot of game play and scenarios with an emphasis on fun, engagement and improvement. Participant Two also desired improvement through working on strengths rather than weaknesses and valued drills (training form), volume of practice, and one-on-one opportunities with players where possible. Participant Two believed net sessions were great for batters in terms of volume but not as beneficial for bowlers. Participant Two did use centre-wicket scenario type training in their coaching practice. They did, however, express a view that they valued net sessions due to the volume of practice you could get with batters. Finally, Participant Three emphasized the importance of developing each participant's 'inner coach' and coaching in a way that required the players to develop their own player-centered goals through game-like practice experiences and reflection on what has happened during play. This belief seems informed by constructivist views and valuing of learner autonomy during practice.

3.1. Coach observations

The results in this section describe the observed coaching styles of the three coaches during their three 60-minute coaching sessions (three coaches times three 60-minute observations = 540 minutes total observation time). All three coaches, when observed through the lens of the Spectrum, were coded as Coaching by Task (Practice) Style B as the dominant coaching style with Participant Two exclusively using Style B. While Style B may be thought of as closed skills or drills practice under control of the coach, we argue that this is not the only case. Style B is from the reproduction cluster and can require the participant to use memory of the coach demonstration and explanation as the cognitive operation. An example of Style B being used in a game like environment was used by Participant Three. Participant Three told the batter his target was 16 runs off 6 deliveries. Participant Three's questioning is below:

> Participant Three: 'What's the field?'
> Bowler: 'Normal ring field.'
> Participant Three: 'What's a normal ring field'? 'So, everyone's up?'
> Bowler: 'Yeah…a mid-wicket.'
> Participant Three: 'He's got everyone up…and you need 16 off the over.'

These are examples of how open-ended questioning can require the participant to recall known knowledge and is therefore not Guided Discovery – Style F. We are not arguing recalling knowledge is not valuable, we are merely suggesting open-ended questioning in this form is not requiring the learner to discover knowledge and would not meet the CA coaching goal of solving a problem. Coaching by Guided Discovery Style F was minimally used by Participant 1 (1.5% of the time) and Participant Three (2.7% of the time) when coaching.

Participant One was also observed using Coaching by Problem Solving (Convergent Discovery) Style G (0.8%) with their players, meaning in the observed sessions they used three coaching styles (Styles B, F and G). Participant Two used one coaching style throughout – Coaching by Task (Practice) – 86%. Participant Three used four coaching styles during the observations, creating learning experiences for their players using Coaching by Individual Programming (Self-Check) Style D (0.4% of the time), Coaching for Creativity (Divergent Discovery) Style H (1.7% of the time) when coaching, Coaching by Guide Discovery Style F – 2.7% and Coaching by Task (Practice) Style B – 82.6%.

Table 2: Coaches observed coaching styles.

Participant	Coaching style used during three 60-minute coaching sessions
Participant 1	Coaching by Task (Practice) Style B – 82.2% Coaching by Guided Discovery Style F – 1.5% Coaching by Problem Solving (Convergent Discovery) Style G – 0.8% Management – 15.5%
Participant 2	Coaching by Task (Practice) Style B – 86% Management – 14%
Participant 3	Coaching by Task (Practice) Style B – 82.6% Coaching by Individual Programming (Self-Check) Style D – 0.4% Coaching by Guide Discovery Style F – 2.7% Coaching for Creativity (Divergent Discovery) Style H – 1.7% Management – 12.6%

From the nine 1-hour observations (three coaching sessions per participant) the coaching styles used in descending order were, Style B, Style F, Style H, Style G and Style D (Table 2). However, whilst a range of styles were observed, the dominant style observed being used by all three participants was Style B. Further, Style B dominated all nine sessions observed being observed between 82–86% of the time.

4. Discussion

Consistent with CA's desire for game play as a coaching approach that fosters player problem solving using game forms (CA, 2022), from the participants' interviews there was a general description of game play being evident in all their self-reported philosophies of coaching. Even though Participant Two indicated a valuing of net sessions, they still made a point of emphasising centre-wicket practice which generally could be assumed to resemble game-like scenarios. Including a lot of game play or game like environments in practice sessions were included in the common coaching philosophy of the coaches. However, there was no mention in the interviews of CA's coaching philosophy of using game play to solve problems, nor of a GSA to coaching. Participant One used words such as scenario and challenge, and Participant Three mentioned using reflection and thinking but not specifically the phrase problem solving. The failure by all three participants to mention CA's philosophy influencing their coaching may reflect coaches not being cognisant of their coach education programs influencing their coaching (Ferner et al., 2023).

Whilst a range of coaching styles were observed, the dominant style observed by all three participants was Style B, observed between 82–86% of the time. Style B requires participants to use the cognitive operation of memory in the reproduction of movement demonstrated and explained by the coach. Research (Hewitt et al., 2016; Pill et al., 2015) has shown that Style B is the most used sport coaching style. Style B is termed Coaching by Task (Practice) and it is not limited to closed or isolated movement skills practice as it may take the form of a game if the players are being asked to replicate known movements and strategies (Pill et al., 2022); that is, practice in context existing skills, knowledge and understanding. The dominant use of Style B in this study is similar to Low et al. (2013) findings that traditionally coaching in cricket involved players spending most of their time in training form or drill like activities typical of common 'net' practice sessions, reproducing existing skills, knowledge and understanding in a relatively stable practice context rather than practicing in the dynamic and more contextually variable situation of playing form or game-like activities. Training Form activities are described 'as activities practised in isolation or in small groups that were devoid of a game play context' (Low et al., 2013, p. 1244) whilst match form is game like or match like conditions. The Spectrum differs from Low et al. categorisation in that it bases the coaching styles definitions around the cognitive requirements of the coaching style. In particular, participants being asked to reproduce skills or knowledge or are they being asked to produce new knowledge (by creativity or discovery) to a problem they have not previously encountered. Participants in Low et al. (2013) research were being perceptually, cognitively and motor skill underdeveloped because most of the coaching activities were training form activities. While in our study, Participants One and Three were observed using some games which required problem solving, some other games were coded as Style B as the participants were not directed to solve a problem or the game required the recall of already known movements to play (memory) the game and not solve an unknown problem.

While Style B coaching dominated in our study, Participant Two was the only coach to use Style B the entire time of their three 1-hour observed coaching sessions. Participant One used three styles (B, F and G) and Participant Three used the most styles (B, D, F and H) of the three coaches involved. The dominant use of Style B may have been influenced by Participant Two 's desire for volume and seemingly valuing time and efficiency. However, the view that volume can only be achieved through traditional cricket coaching may be a misconception. Vickery et al. (2014) suggested game-like environments (Battlezone) have a similar or greater training load to traditional training methods. Participant Two's view that efficiency and volume can only be achieved through net sessions (and not CA suggested approaches) maybe an example of what Jones (2007) described as an everyday coaching philosophy and that coaches are aware of where to find coaching knowledge but fail to see its relevance in their everyday coaching.

Style F (used by Participants One and Three – see Table 1 for definition) was the second most frequently used coaching style

observed being used. However, at other times, Participant One and Three also used open ended questions (a characteristic of Style F) with their participants where the players were retrieving or recalling knowledge or answers previously known, meaning by Spectrum definition, Style B.

Divergent Discovery Style – H was only used by Participant Three. Divergent Discovery Style – H learning episodes are created with the intention for 'players to discover or generate multiple possibilities that satisfy a question or situation' (Pill et al., 2022, p. 80). That is, the coach sets a problem or scenario for the player to solve that has multiple solutions. The player will use creativity or discovery (not recall or memory of a known solution) to produce two or more solutions. Divergent thinking requires idea generation where more than one solution is workable. Divergent thinking is often applied to 'open' problems and challenges where creative solutions are sought (Benedek et al., 2014; Pill et al., 2022). An example of a Divergent Discovery Style – H used by Participant Three was a challenge called 'Hit the clock'. An area was set up on a synthetic cricket pitch with targets (1 o'clock, 3 o'clock, 5 o'clock) represented with markers. One player would under-hand toss a ball which would bounce once before reaching the batter. The batter was tasked with the problem of hitting the targets which they nominated. The coach instructed the batters to 'solve the problem of hitting the target even if the ball is not exactly where you want it. What can you do?' This situation is an example of the researchers seeing that this could be also an example of Coaching by Task (Practice) - Style B if the players already possessed the skill to solve this problem or had solved this problem before. Despite this, the researchers coded this coaching episode as a Production Cluster style as when two styles emerged, the one closest to the Production Cluster was recorded.

Considering all nine hours observed, 6.7% of the coaching styles (Styles F, G and H) required learners to use discovery or creativity as the cognitive operation. Using discovery or creativity is in line with CA's desire for players to learn through problem solving. This 6.7% would represent 36 minutes total time where coaches (Participant One and Three) used coaching styles that required problem solving to be used by the players. We argue that this does not represent a significant amount of time and that the coaches are not meeting CA desired outcomes. CA does not specifically suggest an amount of time that coaches should use a coaching style encouraging player problem solving, nor would we suggest that there is a specific or 'right' number. However, considering Participant Two went the entire time using one style (Practice Style B), it is hard to believe that this would meet CA's desire for coaches to be game-based in their coaching (Cricket Australia, 2022).

The discrepancy between the coaches self-reported coaching styles and what was observed (dominance of Style B) is similar to findings by others (Hewitt et al., 2016; Pill et al., 2016; SueSee & Barker, 2019; SueSee et al., 2019). This suggests that the tenets of GBA coaching, in the Australian context a GSA, may have recognition but lack wide-spread understanding despite being continually being asserted as the underpinning pedagogical expression for junior sport coaching and playing for life (Australia Sport Commission, 2023). Whilst the researchers observed games frequently, what they did not see as often (6.7% problem solving) were games requiring the solving of unknown problems and the use of questioning to encourage players into thinking (reflecting) on their practice. CA's coaching philosophy values solving problems through games however it does not speak about the role questioning plays in a GSA. Others (Ferner et al., 2023) suggested many current coaching education programs speak about coaching styles or methods, however, they fail to show coaches how to effectively implement a coaching philosophy congruent in practice with the coaching styles they promote for coaches.

Another factor that may have influenced the styles used was pedagogical coaching knowledge. Participant Three was the highest qualified (Level 3) coach and a high school teacher. This participant used the greatest number of coaching styles (n=4), had the lowest amount of time coded as management, and spent the most time using coaching styles that required players to solve problems. Whilst the sample size is too small to make causative claims, we suggest this participant's pedagogical content knowledge (PCK) was the highest given their qualifications and may have had some effect. This is in line with others (Roberts, 2011) who recorded cricket coaches desiring more support to implement Teaching Games for Understanding in the United Kingdom when attempting to implement player-centred coaching. The ASC suggests a GSA is a way to modify game strategies and concepts so there are opportunities to develop both skills and an understanding of the tactics of the game' congruently and thereby help develop thinking players (Australia Sport Commission, 2023). The use of inquiry strategies by coaches using a GSA is accordant to coaches creating practice episodes that include using Coaching by Guided Discovery – Style F, Coaching by Problem Solving (Convergent Discovery) – Style G and Coaching for Creativity (Divergent Discovery) – Style H from The Spectrum of Coaching Styles (Pill et al., 2022). The three coaches in this research self-reported using Playing Form (O'Connor et al., 2020) type activities at times (or game-like environments), and in some cases the learning experiences were game-like where participants were required to use perceptual motor skills. However, this is where The Spectrum positions learning episodes differently by defining the coaching styles used based on decision making between the coach and participant to help define the coaching style. We argue that The Spectrum can provide the knowledge, skills and language to assist coaches in creating learning episodes which reflect the tenets of GBA's. This research did not set out to prove that coaches lacked knowledge to implement a GSA, rather than to confirm if their coaching philosophies aligned with their coaching practice. As all three participants, in some capacity, verbalized a valuing of a GSA then it may be presumed, they would use a GSA where and when appropriate. Based on this premise, knowledge of The Spectrum could assist with greater alignment between the assumed coaching style and enacted coaching style (Hewitt, 2015). The Spectrum can provide an integration of declarative (what needs to be done) and procedural knowledge (how it needs to be done) which links back to the coach's pedagogical judgement and decision-making intentions towards implementing a GBA (Pill et al., 2021).

While suggesting supporting coaches' development and improving PCK may assist coaches alignment procedural knowledge relative to using a GBA with declarative knowledge relative to implementation, we note the multi-dimensional nature of coaching children in community cricket. If a coach was using any coaching style, but they believed a participant was not engaged, they very likely would change the coaching episode in the hope of re-engaging the participant. To put this in a context,

CA has its intentions that coaches be game-based, the coach may attempt to apply a version of that through coaching (pedagogical) style and the participant has their own agenda for participating in community cricket –which may or may not align and lead coaches to utter the 'it's fine in theory, but…' (Jones, 2007) disposition towards a GBA. Other research has suggested barriers to coaches' using GBA's include a reluctance to 'let go' of direction and control (Light & Evans, 2010), lack of clarity in coach education as to what a GBA is in practice (Reid & Harvey, 2014), challenges adapting their session plans to the format of a GBA (Thomas et al., 2013), and under-developed PCK regarding questioning skills (O'Leary, 2014), a tenet of a GBA. Specific to cricket coaching, a factor which has been suggested is the excessive reliance on reproductive or direct teaching methods due to the traditional culture associated with the sport (Cassidy et al., 2008; Williams & Hodges, 2005). This includes cricket training frequently occurring in enclosed nets (Low et al., 2103). These factors must also be considered as potential influences on the pedagogical choices of participants in this study.

Conclusion

This research aimed to identify the coaching styles used by three community cricket coaches and if they aligned with their own beliefs about the styles they used, and the goals suggested by Cricket Australia of coaching using an approach that requires problem solving through games. Style B was the most used style and used by all participants in this study. All three participants used Style B over 80% of their coaching time. All the participants reported using games and problem solving (which are suggested components of GBA's) during interviews but only two participants were observed using coaching styles that could create learning episodes that may lead to discovery and problem solving. The results indicate that in some cases, coaching style alignment was observed indicating congruence with self-reported coaching styles or philosophies between Participants One and Three. Whilst Cricket Australia does not stipulate the amount of time coaches should use GBA's, the researchers suggest that 6.7% of the time using a GBA (to create learning experiences requiring problem solving - approximately 36 minutes) out of 9 hours of coaching, will most likely not achieve the aims of player problem solving games (Cricket Australia, 2022). What can be claimed with certainty is that the majority of time players with the coaches in this study were not in environments representing the suggested coaching approach of CA. A lack of alignment exists with Cricket Australia's stated coaching preference (problem solving) and the coaching styles observed during this research. Whilst this research is not a critique of CA's suggested coaching desires, perhaps what is needed is more specific and common language used to describe the coaching styles CA desires community coaches to use. For example, no one coaching style can achieve all aims and some scholars (SueSee et al., 2016; SueSee & Pill, 2018; Pill & SueSee, 2021) have argued that GBA's are more than one style, and a common language is required to diminish confusion. We suggest the Spectrum can play a part in providing coaches with coaching knowledge that assists in alignment of coaching intention and coaching style. Pedagogical content knowledge (PCK) may predict the quality of teaching and the quality of student learning (Baumert et al., 2010; Iserbyt et al., 2020; Meier, 2021). Further, we argue this knowledge may assist coaches to construct coaching episodes that others (Lascu at el., 2021; Low et al., 2013) have suggested are required for the development of cricketers. The Spectrum has been suggested as a way of providing this common language to help understand 'that broad terminology such as GBAs and Direct Instruction do not adequately describe the teaching-learning decisions being made by the coach and player/s' (SueSee & Pill, 2022, p. 132). Currently, CA's 'The Australian Way' does not provide this common language to help coaches see the complexities of being a GBA coach and CA's approach to coaching needs to be revisited if they wish to achieve the outcomes they state.

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Conflict of Interest

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