Shuttle Time For Seniors: The Impact of 8-Week Structured Badminton Training on Markers of Healthy Aging and Evaluation of Lived Experiences—A Quasi-Experimental Study

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SHUTTLE TIME FOR SENIORS: THE IMPACT OF 8-WEEKS STRUCTURED BADMINTON TRAINING ON MARKERS OF HEALTHY AGEING AND EVALUATION OF LIVED EXPERIENCES: A QUASI-EXPERIMENTAL STUDY

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RUNNING TITLE: BADMINTON TRAINING INTERVENTION FOR HEALTHY AGEING

KEY WORDS: Sport; Older Adults; Physical Activity; Intervention Development

ABSTRACT

Background/Objectives: Engagement in sport offers the potential for improved physical and psychological wellbeing and has been shown to be beneficial for promoting healthy ageing. Opportunities for older adults to (re)engage with sport are limited by a paucity of age-appropriate introductory sports intervention programmes. As such, the study evaluated the efficacy of a newly designed 8-week badminton training programme (Shuttle Time for Seniors; STS) on markers of healthy ageing and the lived experiences of participation. *Methods:* Forty-three older adults assigned to a control (N=20) or intervention group (N=23) completed pre-post assessment of physical and cognitive function, self-efficacy for exercise and wellbeing. Focus groups were conducted for programme evaluation and to understand barriers and enablers to sustained participation. *Results:* Those in the intervention group increased upper body strength, aerobic fitness, coincidence anticipation time, and self-efficacy for exercise. Objectively improved physical and cognitive function were corroborated by perceived benefits indicated in thematic analysis. STS was perceived as appropriate for the population, where the age-appropriate opportunity to participate with likeminded people of similar ability was a primary motivator to engagement. Despite willingness to continue playing, lack of badminton infrastructure was a primary barrier to continued engagement. *Conclusion:* STS offered an important opportunity for older adults to (re)engage with badminton, where the physical and psychosocial benefits of group-based badminton improved facets important to healthy ageing. *Significance/Implications:* Age-appropriate introductory intervention programmes provide opportunity for older adults to (re)engage with sport. However, important barriers to long term engagement need to be addressed from a whole systems perspective.

KEY WORDS: Physical Activity, Sport, Older Adults, Intervention Development

INTRODUCTION

Maintaining physical function, independence and quality of life (QoL) are important facets of successful ageing (Anton et al., 2015; Urtamo et al., 2019). Given unprecedented growth in the older adult population (WHO, 2018), promoting healthy ageing is a public health and economic priority (Beard & Bloom, 2015; Cruz-Jentoft et al., 2019). Commonly, the negative impacts of increasing age are associated with a decline in skeletal muscle function, where muscle weakness is associated with reduced physical function, chronic disease, poor QoL and all-cause mortality (Cavel-Greant et al., 2012; Li et al., 2018; Moreland et al., 2004; Wolfe, 2006). Skeletal muscle function is an integral component of the bidirectional relationship between physical function and wellbeing (Steinmo et al., 2014), where an age-induced decline in muscle contractility and impaired physical function can contribute to feelings of social isolation (Nicholson, 2009), depression (Chang et al., 2017) and suicidal ideation (Noh & Park, 2020), which in turn cause further impaired physical health (Davies et al., 2021).

Many detrimental effects of ageing are ameliorated by physical activity (PA) (Cunningham et al., 2020; Vogel et al., 2009a). Physically active older adults have reduced risk of all-cause mortality, development of non-communicable diseases, falls, activities of daily living (ADL) disability and cognitive decline resulting in improved QoL and a healthier ageing trajectory (Cunningham et al., 2020). Globally older adults are among the least physically active groups (Hallal et al., 2012). The most recent data indicates that 70% of 65-74 year olds in England are active, declining to 31% in those over 85 years (NHS-Digital, 2020). Poor PA engagement in older adult populations has been attributed to physical, behavioural, and economic constraints. More specifically, physical capability, lack of enjoyment, fear of injury, low-self efficacy, financial implications and a lack of age-appropriate opportunities are regularly cited barriers (Gellert et al., 2015; Gray et al., 2016a; Horne et al., 2013). Effective, inclusive and sustainable ways to promote PA and support long-term participation have become an essential part of public health strategy (Public Health England, 2021), where the COM-B model at the heart of the Behaviour Change Wheel (BCW) explains how capability, opportunity and motivation are the key facets of behaviour change (Michie et al., 2011).

Age-appropriate group-based exercise, using sport as a vehicle, has received recent attention where combining the physical and social aspect of sport has been shown to be effective for improving physical and psychosocial facets important for the promotion of healthy ageing (Duncan et al., 2022; Gayman et al., 2017). Whilst individuals that continue to play sport across the life course experience health benefits (Oliveira et al., 2023), it is recognised that sport has not been widely explored as a PA opportunity for older adults (Jenkin et al., 2017). There is a scarcity of research dedicated to the development and assessment of the effectiveness of sports interventions suitable for older age groups. Among the limited studies that have attempted to address this issue, most have utilised soccer and match play as the means of investigation (Arnold et al., 2015; Duncan et al., 2022; Reddy et al., 2017). Given that match play requires some degree of tactical and technical skill competency, and that perceived capability and self-efficacy are commonly cited barriers and enablers to PA engagement in older adult populations (Gray et al., 2016b; Lees et al., 2005), match play focused interventions may limit broader engagement. As such, age-appropriate structured and progressive training interventions are needed to help overcome well cited capability and opportunity barriers to PA and to aid in providing the impetus for sustained PA behaviour. Given the limited logistical burden and impact of seasonality, combined with its physiological, biomechanical and cognitive demand (Manan et al., 2018; Ooi et al., 2009; van de Water et al., 2017), a structured and progressive programme of badminton for older adults, that harnesses the superior psychosocial benefits of group based exercise, is well placed to develop physical health, wellbeing and QoL. Recent evidence demonstrates benefits of the Badminton World Federation's (BWF) Shuttle Time programme, a school-based badminton intervention that has been shown to improve fundamental movement skills in children (Chen et al., 2021; Duncan et al., 2020). However, to date there is no evidence to support the efficacy of a badminton specific intervention for older adults.

Evidence suggests that psychosocial factors such as enjoyment, social and environmental support rather than biomedical variables have greater influence on sustained participation in exercise (Lautenschlager et al., 2004; Zubala et al., 2017). Older adults are more compliant with PA interventions that promote self-efficacy (Chase, 2013) and where the focus is on competency rather than outcome (King, 2001). Based on these principles we have developed the first badminton-based

intervention for older adults (Shuttle Time for Seniors) that is inclusive of ability, fitness, and physical function. Using an adapted version of BWF's Shuttle Time, the programme focused on the development of social health and the physical capabilities and technical abilities to develop badminton specific movement competency, where such benefits will translate into improved functional fitness, self-efficacy for exercise and wellbeing. More specifically, the present study used a mixed methods approach to evaluate the effects of the 8-week Shuttle Time for Seniors (STS) intervention on functional fitness, wellbeing, badminton specific skill and to understand the lived experiences of undertaking in STS. As such, this study will provide evaluation of the effectiveness of a badminton specific intervention for older adults and gain participant's perspectives to refine the programme and to understand barriers and enablers to sustained engagement.

METHOD

Participants

Following ethics approval from the host institute and written informed consent, a quasi-experimental design was used where 50 participants were recruited and assigned by the lead investigator to a control (N = 26) or intervention group (N=24). Groups were matched for age, body composition and baseline functional fitness. The STS intervention was designed specifically for adults aged 60 yrs. and over, with no or limited recent badminton experience, and to be inclusive of fitness capabilities. Participants were screened using the Physical Activity Readiness Questionnaire (PAR-Q), a self-screening tool to determine safety and possible risks to PA engagement based on health history. Participants were excluded if they had been diagnosed with a chronic medical condition that prevented safe completion of the assessments or had a musculoskeletal injury/condition that had either not been fully rehabilitated or would be aggravated by increased PA. Six members of the control group did not complete the follow-up assessment for reasons unstated. One member of the intervention group did not complete post assessments due circumstances not associated with the intervention. As such, the final study sample included 43 participants (N=20 in the control group and N=23 in the intervention group).

A sequential mixed method, pragmatistic approach was utilised to address the primary aims of the project where the experimental procedures were split into two distinct parts. In part one, participants completed a battery of healthy ageing assessments 8-weeks apart (Fig 1). Participants in the control group were instructed to continue with their habitual PA behaviours. Participants in the intervention group completed an 8-week badminton intervention, STS, designed specifically for this project to develop functional fitness and badminton specific skill. In part two, the lived experiences of participants that completed the intervention was assessed by conducting and analysing information gathered from focus groups. All assessments took place between January 2022 and May 2022.

[Insert Figure 1 Here]

Part 1: Healthy Ageing Assessments & Shuttle Time for Seniors

All participants completed questionnaires to evaluate wellbeing, perceived barriers to exercise and self-efficacy for exercise following assessment of body composition, coincidence anticipation time and functional fitness. Assessment took place at either the host institute's human performance laboratory or at a community sports centre. Assessments were carried out in the order outlined below.

Self-Efficacy for Exercise, Wellbeing & Benefits and Barriers to Exercise

Each participant completed paper-based versions of the Warwick-Edinburgh Mental Wellbeing Scales (Tennant et al., 2007) (WEMWBS) Self-Efficacy for Exercise Scale (SEE) (Resnick & Jenkins, 2000), Exercise Benefits/Barriers Scale (EBBS) (Sechrist et al., 1987).

Body Composition

Participants were asked to remove shoes, socks and heavy clothing before stature (cm) was assessed using a stadiometer (SECA Instruments Ltd., Germany). Body mass (kg), muscle mass (% of total body mass), and fat mass (% of total body mass) were measured using hand to foot multi-frequency bioelectrical impedance (MF-BIA; TANITA MC-780, TANITA, Japan; impedance frequencies 5, 50 and 250kHz). MF-BIA has been shown to have acceptable accuracy compared to

dual-energy X-ray absorptiometry (DEXA) for measures of adiposity and lean mass (Faria et al., 2014) and is reliable for assessment of body composition in older adults (Yamada et al., 2017). MF-BIA devices allow for accurate assessment irrespective of time of day and without the need to impose nutritional constraints (Verney et al., 2015). Body mass Index (BMI; kg/m^2) was determined as body mass / $stature^2$.

Coincidence Anticipation Time

Coincidence anticipation time (CAT) was measured using a Bassin Anticipation Timer (Model 35575, Lafayette, USA). CAT refers to the ability to predict the arrival of a moving object at a particular point in space and effectively coordinate a movement response (Payne, 1986). CAT is therefore considered a test of perceptual-motor coupling requiring integration of sensory-cognitive processing and sensory-motor integration (Fleury & Bard, 1985). CAT is fundamental to a multitude of activities of daily living such as making judgement of when to safely cross a busy road, pick up an object, shake hands or walk through a crowd of shoppers.

Participants were asked to stand directly behind the Bassin Anticipation Timer, which was set up vertically from the front of them and angled toward them at 45^o. The assessment was set-up using three sections of runway (2.24 m) where during completion of each attempt the system's LEDs were sequentially illuminate in a linear pattern moving distally to proximally in front of the participant. Participants were asked to stop the sequential movement of illuminated LEDs as close to the arrival of the stimulus at the target location (runway 3, light 13) as possible using either a button press (control group) or by swinging a badminton racquet underarm through the system movement sensor switch (intervention group). Each test started with random cue delay between 1-2 s to prevent familiarity with the initiation of the test influencing performance. Participants completed 10 practice attempts at each of the assessment speeds before completing 10 recorded trials. 3 mph and 8 mph were evaluated to represent slow and fast stimulus speeds respectively (Tallis et al., 2013). For each of the recorded trials, the time (ms) that the sequence of illuminated LEDs was stopped prior to or following the target was recorded.

For each participant, raw scores across each of the stimulus speeds were summarised into three error scores as per previous work (Tallis et al., 2013). Constant error, the temporal interval between the arrival of the visual stimulus and the end of the participant's motor response, was recorded as a representation of the mean response of an individual and the direction of error: early or late. Variable error, the standard deviation of mean response, was recorded as a representation of variability/inconsistency of responses. Absolute error was also determined as the absolute value of each raw score disregarding whether the response was early or late.

Functional Fitness

Given their links to all-cause mortality (Bohannon, 2019), grip strength and gait speed were measured, followed by completion of the Senior Fitness Test (SFT).

Isometric hand grip strength for the dominant side was measured following the procedures outlined by the American Association of Hand Therapists as described in previous work (Wearing et al., 2018). Participants were seated in a chair without arm support, with feet resting on the floor and hips flexed to 90^{o}. The assessment was carried out with the elbow of the assessed arm flexed to 90^{o}, the forearm neutral and the wrist withing 15-30^{o} of extension (dorsiflexion). Initially the handle of the hand grip dynamometer (Takei 5401, Takei Scientific Instruments, Japan) was adjusted to a position where the participant felt able to squeeze as hard as possible follow submaximal attempts. During measured assessments, participants were asked to squeeze the handle as hard a possible for ~5 s. Participants were permitted three attempts, separated by a minimum of 30 s of rest. The highest value was used for further analysis.

Normal 4-meter gait time was measured using timing gates (Brower TCi, Brower Timing Systems, UT, USA). From a standing start, participants were asked to walk at "the speed at which you would walk to the shops". As per previous work (Forte et al., 2013), in order to account for acceleration, timing gates were placed at the 2nd and 6th m and the mean time of three attempts was recorded.

Further assessments of functional fitness followed the procedures outlined in the Senior Fitness Test (SFT) battery (Rikli & Jones, 1999b). The SFT is valid, reliable and allows performance comparison to age-specific normative values and age-appropriate thresholds for maintaining functional independence (Rikli & Jones, 1999a, 2013). Participants completed Arm Curl (upper body strength endurance), Chair Stand (lower body strength endurance), Timed-Up & Go (lower body power, balance and agility), Chair Sit & Reach (lower body flexibility), Back Scratch (upper body flexibility), and the Six-Minute Walk (6MWT; aerobic endurance) assessments as per the procedures outlined in the supplementary material (ST1). In each case, performance was assessed following demonstration and practice attempts.

Short Serve Test

Short serve ability of the participants involved in the intervention was assessed using the procedure outlined by Edwards et al. (2005). On a badminton court with standard measurements, participants were asked to stand in the front corner of the right service box, where the centre line and service line intersect. Using a backhand serve, participants aimed for a 1-meter grid placed at the front of the receiver's service box, where the short service lines and centre court line were used as two edges of the square. Following two practice attempts, performance was assessed across 10 trials with a 'miss' recorded if the shuttle did not fall within the grid and a 'hit' recorded if the shuttle fell within the grid.

Shuttle Time for Seniors

Those in the intervention group completed the STS programme. STS was developed using the original BWF Shuttle Time programme (BWF, 2023) as a basis. The original BWF Shuttle Time is a 22-lesson school badminton programme, where fun/competitive game-based scenarios are used to develop physical, technical and tactical competency for badminton. The 8-week STS programme was designed by the research team (MN, JT, EE, RM, DR), all of whom have a sport science background and have either coaching experience at grassroots and professional level and/or have delivered successful exercise innervations with older adults as part of previous research projects.

The STS programme focused on a constraints-led approach which was supported by demonstration, opportunity for trial and error and coach feedback. Each session was split into four distinct sections, consisting of a warm-up, game-type activity, constrained match play and a cool down. Game-type activity and constrained match play were designed around specific session themes based on the principles of BWF Shuttle Time programme for children. The 8-week programme focused on developing fundamental badminton skills, movement competency and was progressive in PA demand. Whilst these principles mirror those of the BWF Shuttle Time programme for children, STS was designed to provide an age-appropriate challenge considering individuals that wanted to (re)engage with badminton through to those where the programme provided first exposure to the sport. The original Shuttle Time programme is designed as an introductory programme for delivery by physical education teachers, where each session focuses on the development of specific badminton skill or tactic. Whilst skill and tactical development were an important focus of STS, where basic badminton skills were introduced and reinforced within and between sessions, skill and tactical development was integrated into a weekly multicomponent programme. Specifically, activities were designed to develop important physical capabilities that deteriorate with increasing age (muscular strength and power, aerobic capacity, balance, flexibility, and agility) using movement patterns that mimicked ADL. Effective multicomponent exercise programmes represent an important strategy to facilitate the achievement of physical activity guidelines.

Feedback on STS was sought from older adults with limited or no recent badminton experience (N = 2) and a practitioner with no specific experience of badminton but a professional in delivering fitness classes for older adults. In all cases, an electronic version of the draft STS programme was sent to participants recruited and either verbal or written feedback was provided. The purpose and importance of the programme was recognised in the feedback, as was the focus on elements further to match-play. An 8-week intervention with one-hour session was deemed to be appropriate to provide an insight into the sport. With respect to development, feedback was specific to considering further differentiation of activities to encompass a broader range of physical capabilities. Consideration of specific health conditions and/or physical constraints were most frequently suggested, where arthritis in hands, knees and back, poor balance and coordination were

mentioned. More broadly, providing opportunity for social engagement and consideration of how to provide an appropriate level of challenge in a mixed ability group were suggested to be important. This feedback was reviewed by members of the research team (MN, JT, EE) the STS was modified. Details of the STS programme delivered can be found as supplementary information (SF1).

STS was delivered on a single occasion in a group format where participants attended a single 60-minute morning session (Friday's at 11:00 am) once per week. Sessions took place in a sports hall at the host institute, with markings for four badminton courts. Sessions were led by an individual with a sport and exercise science background who had coaching experience of youth and adult team sport and martial arts, but no experience specifically of coaching badminton or sport for older adults. Sessions were supported by a final year BSc. Sport and Exercise student, with no previous badminton coaching experience, who supported the lead coach to gain experience of working with older adults for PA promotion. The threshold for data to be included in the final analysis was attendance at a minimum of six of the eight planned sessions. Eight of the participants (35%) attended all eight sessions, whilst 11 (48%) and 4 (17%) attended seven and six sessions respectively. On the small number of occasions where participants were unable to attend, medical appointment, illness, or planned vacation was cited.

Statistical Analysis of Data

Following appropriate checks of normality and homogeneity of variance, parametric statistical analysis was performed. Body composition and functional fitness were assessed using two factor mixed model ANOVA. Group (Control vs. Intervention) was used as the between subjects factor and Time (Pre vs Post) used as the within subjects factor. Significant interactions were explored with Bonferroni corrected pairwise comparisons. Partial eta squared (ηp^2) was calculated as an estimate of effect size and interpreted as small (>0.01), medium (>0.06) or large (>0.14) (Richardson, 2011). On a small number of occasions, normality was violated. However, ANOVA is still considered a robust statistical method in such cases (Blanca et al., 2017).

Performance in the short serve test was evaluated using a paired t-test and differences in age and height between the intervention and control groups were evaluated using an independent

samples t-tests. For t-tests and pairwise comparisons, Cohen's d was calculated and corrected for bias using Hedge's *g* (Lakens, 2013). Hedges *g* effect size was interpreted as trivial (<0.2), small (<0.6), moderate (<1.2) or large (>1.2) (Hopkins et al., 2009). Data are presented as mean ± S.E.M. Statistical analysis was performed using SPSS 26.0 (Chicago, IL, USA) and graphical presentation of data was performed using GraphPad Prism (Version 10.0, San Diego, California). Statistical significance was *a priori* set at an alpha level of $P<0.05$.

Part 2: Lived Experiences of Shuttle Time for Seniors

To ensure explicit and comprehensive reporting, the consolidated criteria for reporting qualitative research was used to guide the reporting process (Tong et al., 2007). Information regarding experience of the research team, reflexivity, and relationship with participants is outlined in as supplementary information (SF2) and the COREQ checklist with corresponding page numbers in SF3.

Study Design: Selection, Setting, Data Collection

A phenomenological approach was adopted given the intention to gain understanding of STS from the perspective of those who experienced it. Phenomenology is considered particularly well-suited for investigating intricate challenges in health professions education (Neubauer et al., 2019). A purposive sample, which were all participants who had completed the STS intervention, were recruited via face-to-face discussion upon completion of the final session. Homogenous focus groups were used as the preferred method for understanding the collective views of the participants that completed the intervention based on similar characteristics i.e., their perceived ability. Within each of the STS sessions, differentiation of tasks was achieved by manipulating the challenge on each badminton court with progressing task difficulty. Participants were free to choose the level of challenge that best suited their ability and were free to move between courts within and between tasks. Over the course of the intervention this naturally evolved into the formation of three groups based on perceived capability. Focus groups were selected to enable collective discussions about participants similar experiences whilst encouraging a range of responses. Given that the group had played badminton together and engaged in regular social interaction it was felt that group dynamics

would work well putting the interaction into the hands of the participants rather than the researcher to enable in-depth discussions about their experiences and the group process assisting group members to explore and clarity their points of view (Liamputtong, 2011). An upper sample size strategy was used in line with the study goals, in that all involved (n = 23) were invited to take part (7 declined due to commitments that prevented attendance at the time the focus groups were scheduled), representing 78% (18/23, 6/8 females) of participants. Participants were White British, typically of middle to high socioeconomic status, were either retired or semi-retired and had a range of hobbies including gardening, walking and volunteer work. Individuals in the high perceived ability group (focus group 2), more frequently reported engagement in structured sport (e.g. tennis) and exercise classes. All focus groups were conducted at the university site at the same time for which participants were attending the badminton intervention. This was an environment for which they were familiar with and had been attending weekly. McNamara's eight principles of interviewing were followed (McNamara, 2009).

In accordance with published recommendations, each focus group consisted no more than seven participants, lasted ~90 min, and used a single semi-structured technique based on six pre-determined, open-ended questions (Gill et al., 2008) outlined in the supplementary information (SF3). No repeat interviews were conducted. Questions were based on building rapport and developing an understanding of three topic areas, interests and expectations of the programme, experience of the programme, and sustainability of behaviour and hopes for the future in line with guidance from constructing effective questions for focus groups (McNamara, 2009). EE developed the interview schedule was piloted with the third and last author to help the researcher identify any flaws or limitations prior to data collection (Kvale, 2008). Feedback from the pilot phase was used to adjust the interview schedule to reduce misunderstanding and to develop prompts to gain further understanding (Creswell, 2007; Hagens et al., 2009). Three focus group discussions were scheduled. Focus group discussions were facilitated by MD and MN with JT and EE observing the discussions and taking field notes.

Audio recordings of each focus group were collected using an Olympus DS-2400 digital voice recorder, lasting 48.19 min (FG1; N = 5; 4F), 49.26 min (FG2; N = 6; 1F) and 73.00 min (FG3; N = 7; 1F). Field notes were also taken. Audio was transcribed verbatim using Microsoft Word (Microsoft Corporation, Washington, US.) and checked manually by two members of the research team (EE, JT). Transcripts were anonymised using [Number] to represent the focus group, [Number] to represent the participant, [M/F] to represent the participant's sex. These were then manually checked by EE. Transcripts were not returned for comment or correction given the four dilemmas that are discussed in detail in the work of Mero-Jaffe (2011). Instead, paraphrasing was used during the interviews to check that the researcher had understood the views of the group and participants provided the opportunity to reflect upon this. Given the nature of the purposive sampling strategy and the goal of the study to speak to all involved (upper sample size limit), recruitment could not continue until the point of saturation where no new relevant knowledge was obtained.

Qualitative Analysis

Inductive thematic analysis was conducted as suggested by Braun and Clarke (2006). Key themes were identified via a step-by-step analytical process involving data familiarisation through transcription, reading and re-reading the transcripts, code generation where short descriptive labels were assigned to the entire data set, categorisation where similar descriptive labels formed categories, searching for and reviewing the themes, and defining and naming themes. This process was conducted by one author (EE) and resulted in a thematic map with themes, subthemes, associated quotes and relationships. Throughout the focus groups, analytical process and reporting of results, field notes (during), reflexivity, debriefing and critical friend discussions (MD, MN, JT, EE) were held to be transparent about selective and interpretive bias, to debate and re-define themes and develop rigour (Lincoln & Guba, 1985; Smith & McGannon, 2018).

RESULTS

Part 1: Healthy Ageing Assessments & Shuttle Time for Seniors

Participant Characteristics & Body Composition

Age and height did not differ between intervention and control groups (Table 1. P>.694; g<.392).

[Insert Table 1 Here]

For body mass and BMI, there was no significant Group*Time interaction (Table 2. P<.149; ηp^2<.051), no main effect of group (Table 2. P>.309; ηp^2<.026), but both body mass and BMI were lower when assessed post the intervention period (Table 2. P<.023; ηp^2>.121). For percentage muscle mass and fat mass there was no Group*Time interaction (Table 2. P>.176; ηp^2<0.045), no main effect of group (Table 2. P=.365; ηp^2=.021), or main effect of time (Table 2. P>.139; ηp^2<.055).

[Insert Table 2 Here]

Functional Fitness

For Chair Stand performance, Chair Sit & Reach left, Back Scratch, TUG, HGS and 4m gait time there was no Group*Time interaction (Fig 2A, D-G. p>.052; ηp^2<.089), no main effect of group (Fig 2A, D-G. p>.320; ηp^2 <.024) and no main effect of Time (Fig 2A, D-G p>.381; ηp^2 <0.020). Similarly, for 4m gait time there was no Group*Time interaction (Fig 2I. p=.075; ηp^2 =.075) and no difference between groups (Fig 2I p=.939; ηp^2 <.001). However, irrespective of group, 4m gait time was reduced following the intervention period **(**Fig 2I p=.001; ηp^2 =.239).

For arm curl performance, Chair Sit & Reach right side and 6MWT, there was a significant interaction (Fig 2B, C, J. p<.024; ηp^2 >.118). Pairwise comparisons indicated that prior to the intervention, Chair Sit & Reach right performance was better in control group compared to the intervention group (Fig 2C. p=.009; *g*=.84). There was no difference in arm curl performance prior to the intervention period between the intervention and control group (Fig 2B. p=.144; g=.49). Following the intervention period, the number of arm curls completed in the control group had reduced (Fig 2B. p=.019; *g*=.34) but had increased in the intervention group (Fig 2B. p=.022; *g*=.32). Pairwise comparisons further indicated that 6MWT distance increased following completion of the intervention (Fig 2J. p=.005; *g*=.34), to a level that was greater that the control group (Fig 2J. p=.013; g = .64).

There was no difference in 6MWT distance between the groups prior to the intervention period (Fig 2J. p=.480; *g*=.31). Performance in the short serve test improved following the intervention (P=.008; *g*=.910).

[Insert Figure 2 Here]

Coincidence Anticipation Time

For VE at 3mph there was no Group*Time interaction (Fig 3B. p=.161; ηp^2=.049), no main effect of group (Fig 3B. p=.193; ηp^2=.042) and no main effect of time (Fig 3B. p=.460; ηp^2=.014). For CE at 3mph there was no Group*Time interaction (Fig 3A. p=.161; ηp^2=.049), however CE was lower in the control group (Fig 3A. p=.002; ηp^2=.224), and irrespective of group, was reduced following the intervention period (Fig 3A. p=.019; ηp^2 =.131). For AE at 3mph there was a significant interaction (Fig 3C. p=.015; ηp^2=.139). Pairwise comparisons indicated that prior to the intervention performance in the control group was better than that of the intervention group (Fig 3C. p=.003; *g*=.96). Furthermore, the intervention was effective in improving AE (Fig 3C. p=.005; *g*=.57).

For VE at 8mph there was no Group*Time interaction Fig 3E. p=.116; ηp^2=.060) and no main effect of group (Fig 3E. p=.397; ηp^2=.018). However, VE was reduced following the intervention period (Fig 3E. p=.028; ηp^2=.115). For both CE and AE measured at 8mph there was a Group*Time interaction (Fig 3E&F. p<.002; ηp^2>.097). Pairwise comparisons indicated that CE and AE performance were better in the control group (Fig 3E&F. p<0.029; *g*>.70), and in both cases were improved following the completion of the intervention (Fig 3E&F. p<.002; *g*>.68).

[Insert Figure 3 Here]

Self-Efficacy for Exercise, Wellbeing & Benefits and Barriers to Exercise

For SEE there was a significant Time*Group interaction (Fig 4A. P=.006; ηp^2=.179). Pairwise comparisons indicated that prior to the intervention period, SEE was higher in the control group (Fig 4A. P=.005; *g*=.926), but there was no difference between groups at the end of the intervention (Fig 4A. P=346.; *g*=.298). SEE increased following the intervention (Fig 4A. P=.004; *g*=.503), with no effect in the control group (Fig 4A. P=.289; *g*=.271). For WEMWBS there was no Group*Time

interaction (Fig 4B. P=.381; ηp^2=.020), no main effect of time (Fig 4B. P=.680; ηp^2=.004) and no main effect of group (Fig 4B. P=.210; ηp^2=.040).

For the total score of the EBBS there was no significant Time*Group interaction (Fig 4C. P=.132; ηp^2=.062), no main effect of group (Fig 4C. P=.310; ηp^2=.029), or no main effect of time (Fig 4C. P=.596; ηp^2=.008). Similarly, for the barriers sub-scale, there was no significant interaction (Fig 4C. P=.772; ηp^2=.002), no main effect of group (Fig 4C. P=.251; ηp^2=.036), or no main effect of time (Fig 4C. P=.772; ηp^2=.002). For the benefits sub-scale, there was a significant Time*Group interaction (Fig 4C. P=.016; ηp^2=.151). Pairwise comparisons indicated that irrespective of time, perceived benefits did not differ between groups (Fig 4C. P>.162; *g*<.464). However, perceived benefits increased following the intervention (Fig 4C. P=.012; *g*=.582), with no effect in the control group (Fig 4C. P=.356; *g*=.213).

[Insert Figure 4 Here]

Part 2: Lived Experiences of Shuttle Time for Seniors

Questions were based on developing an understanding of three areas 1) interests and expectations of the programme, 2) experience of the programme, and 3) hopes for the future. The topic, followed by the main themes and sub themes, if relevant, are presented below. A summary of the analysis is presented in Figure 5 and a more detailed coding tree presented in supplementary file 4 (SF4).

[Insert Figure 5 Here]

Interest and expectations of the programme

When asked to discuss their interest and expectations for the programme, three themes (prior experience, the opportunity, social persuasion) for interest in the programme were identified and two for expectations of the programme (perceived physical and psycho-social benefits, unsure).

Theme 1: Prior experience

This theme encapsulates participants positive experience of a racquet sport, being involved in a previous project which they enjoyed and felt the value of, or lack of experience with badminton, which

drove interest for the project. In group two, who perceived to be of higher ability, prior experience of badminton was commonly shared, but this was a long time ago or of other racquet sports (i.e., tennis) which they believed would help. In other groups, most had limited experience or had never played badminton. For these, it was an opportunity to try something new, with some reflecting how they wished they had played when they were younger.

> *'Well I might have played five games of badminton in my whole life but last time was 30, 40 years ago. So badminton was all new. But obviously I played tennis, so I got it. I can can hit a ball …' (2.4, M)*
>
> *'I thought, I've never played badminton. And I thought, well, that's a, that's a good reason to do it. Why not do it and find out whether, whether you enjoyed it or not. And the actual program, I actually enjoyed it and would actually do fancy taking it off' (*3.1, M)

Theme 2: Physical and psycho-social opportunity and perceived benefits

The opportunity to meet new people, learn a sport/skill and have fun as well as to commit to something, or provide a kick starter to that commitment, was felt similarly amongst groups. Particularly the characteristics of the group were important, believing it to be an opportunity to join likeminded people at similar levels to them. Particularly participants shared how without this opportunity they would not have been able to take up badminton on their own. For individuals in group 1 and 3 specifically, the opportunity for physical exercise was commonly shared, explaining how it would provide a good 6-8 weeks of exercise.

> *'this looked like an ideal opportunity to meet people of a similar age, similar ability, um, and sort of see, enjoy the social side of things perhaps. Um, cuz I was always afraid to try and join any club age wise, not good enough and not fit enough. And whereas joining these people, perhaps they're a similar ability, similar age group and, um, you know, similar, similar fitness levels and, uh, I felt more comfortable with that side of things' (3.4, M)*
>
> *'Exercise for me, I thought, well, it'll be a good six or eight weeks of exercise'* (1.4, F)

Given that participants were interested in the programme for the perceived physical and psycho-social opportunity, their expectations of the programme also focused on the physical and psycho-social benefits. For group 2 specifically, the physical and psycho-social benefits were to relearn or reconnect with badminton. While participants reported perceived benefits, it was

commonly shared that they were not quite sure on how this would be done within the specifics of the programme.

> *'I found it a focus to come back to doing things and I thought, well yes, I used to do that. And um, I found it really encouraging from that point of view. I wouldn't have done it on my own. So I would never have played badminton again... It fell apart in days gone by simply cuz my life changed, the people I used to play with. You know, I went to live and worked abroad, so couldn't play with them. Um, so it was a reconnection that I thought, oh yeah, that'll be fun' (2.6.M)*

Theme 3: Social persuasion

For some individuals, they were encouraged to take action by social persuasion by individuals who either asked them to do it with them, encouraged them to go along with them or signed them up.

> *'Well, for me, [friends name] asked me if I'd, uh, I'd do it cause they were looking for, for people and it was like a bit of a kickstart cause I hadn't done anything for nearly a year' (1.5, F)*

Programme Evaluation

Discussions around what participants thought about the programme were positive and led to three main themes (1. Programme delivery, 2. Perceived impact of the programme on their wellbeing, 3. Reinforcing and disabling factors; ability, opportunity).

Theme 1: Programme delivery

This theme encapsulated all aspects related to participants experiences of what was delivered and how this was delivered. This theme contains three sub-themes (design & implementation appropriate for over 60's, coach behaviours: a need for autonomy vs direct instruction, and practical issues).

Subtheme 1: Design & implementation appropriate for over 60's

Considering the design and implementation, all groups felt that the programme was appropriate and well-structured for over 60's. Participants reported that there was a slow build up which was appropriate, felt that the programme was well designed for those who had not played before, but that the balance was right. Constrained match play was perceived to be the best part of

each session, but participants recognised the benefits of exercises and activities transferring to constrained match play. Participants would have liked the session to be extended to allow longer time for match play, however, they reflected that this may not be inclusive for all.

> *'Yeah. Cause I, well I quite liked the way it worked over the eight weeks, the slow build up and we got better and better and then I thought by the state time, the eight weeks was over, we were all ready to start to play games' (*3.3, F)*' I, I actually thought it was well structured that people, they had a group of over sixties come in and had no real idea about fitness levels. And so people were able to grade themselves on this and think, well, and then slowly get into it and Okay. Yeah. And then try and hit the shuttle to the back of the court. And I, I, for could never manage it, but, uh, it's that kind of level there. You slowly realized that, yeah, I can do this. So I mean, I am quite capable of doing this'* (3.1, M)

> *'…it all built up. I enjoyed every week... I did like playing the games at the end, but then at the beginning I probably wouldn't have been able to have played those games'* (2.3,F) *Thought maybe, you know, if you had a longer session you you might actually actually get a bit more ba..badminton in as well. I know you were trying, you know, generally it was like good half, of the hour was spent various exercises and warmups and stuff like that and yeah, the actual playing was was 10, 15 minutes. You know, and I think you, you could have done with a longer, a longer, you know, may you maybe an hour and a half session It might actually get, get yourself a good off hour play every time'* (2.4, M) '*Difficult with an hour and a half sessions, again if you make it more inclusive, include at the bottom end. Some people with those health issues, would be struggling' (2.1, M)*

For group 3 only, the dose was considered to be a 'good hours' worth of exercise' reporting activities led to sweating, muscle work and hand eye coordination. Specifically, participants shared how the warm up made them out of breath but it was self-paced and they could stop if they needed to.

> *'… when we were throwing the shuttle cock cuz it was giving you, making these muscles work with both hands, you know, I thinking, oh this is hard work, you know, I'd rather have a rack <laugh> in back and we were really pushing it, we were all sweating, weren't we*' (3.6, M)

Subtheme 2: Coach behaviours: a need for autonomy vs direct instruction,

Coach behaviours were discussed in how the intervention was delivered. Groups felt that the coaches were skilled physically and interpersonally but depending on their ability they experienced different input or wanted different input from the coach. Group 3 who perceived themselves to be less able reported how they received demonstration and instruction. Group 1 and 2 wanted more direct specific technical instruction from the coaches alongside wanting more information on why they were doing the activity.

'He's so personable. He is. And that is really important without being patronizing because younger people don't always engage, engage that Well and because they did jokingly say when we first came in, uh, there will be some trainees and, but they were very good as well actually. I thought they were all very sort of pleasant' (1.6, F)

'No, no, that's right. I think, I think the ambition, um, of the, of the programme I think, I think it was, it was about right to be honest. I think it would've, it obviously would've been nice to have sort of started at week one and by week eight become a super duper badminton player. But I think, I think that's a bit too ambitious. But I think that certain, certainly it would've, um, certainly I would've um, welcomed a bit more technical. Yes. Input is, I think that's what you're saying in terms of, cause I, my back hand's useless really about and I would've like' (3.6, M)

There were also differences between groups related to autonomy and direct instruction. For group 3, they reported the importance of choosing the court and having the choice to stop when they needed to. This was recognised by group 1 and 2 but they identified how groups stayed together and thus they wanted to be directed to circulate and play different people.

'Yeah. I quite like the fact that we, yeah, we stopped, we, we picked the courts. Yeah. And I haven't got a clue where I fit into everything, but, um, I was a bit, I was kind of happy with myself because I could, I could still run and I could hit things. Maybe not all the time, but we were all about the same level really. So it wasn't a big problem. No. And there's a couple that were pretty good, especially with the drop shops and I think done that again, you, I should realize that' (3.6, M)

'Yeah. And also maybe circulating more, um, I was on the bottom court but we didn't play with the people next door to us so we became a self-selecting small group. I think that could have been mixed up a bit '(2.6, M)

Subtheme 3: Practical issues

All groups outlined issues with the delivery specifically related to acoustics and too many individuals on a court. It was felt that it was difficult to hear the instructions and information due to the acoustics of the room.

'I think there were one or two sort of practical issues that, that could perhaps be ironed out for a future program. For example, the, the number of courts that we had wasn't quite enough for the number of people that we had. So, you know, there was a certain amount of waiting to go, you know, cycling onto the, onto the court and things like that, which was mildly frustrating. Nothing, nothing major, but just mildly frustrating. So I think if the, you know, there were quite a lot of people on the programme altogether and, and um, we could have probably done with a few more courts to, to uh, optimize the thing from that point of view' (2.5, M)

'*Um, you know, there may be more than four people to a court, you know, explaining a little bit more. And um, also the, um, acoustics in the badminton court make it very difficult for you to hear what's being said. And quite often we were like, What, what did you say? What did you say? And I dunno how you get around that. I really don't. Yeah, I don't'* (1.5.F)

Furthermore, for those who felt more able they would have liked longer in the session (1.5 hours) to enable them more time for match play and a programme that extended beyond 8 weeks, ideally 10-12 weeks, where there was more specific focus on the development of technical competency and further understanding of competitive match play rules.

> *'Thought maybe, you know, if you had a longer session you you might actually actually get a bit more ba..badminton in as well. I know you were trying, you know, generally it was like good half of the hour was spent various exercises and warm ups and stuff like that and yeah, the actual playing was was 10, 15 minutes. You know, and I think you, you could have done with a longer, a longer, you know, maybe an hour and a half session. It might actually get, get yourself a good half hour play every time '(*2.4, M)

Theme 2: Perceived Impact of the Programme on Wellbeing

Participants reported perceived changes to wellbeing as a result of the programme. These factors were interlinked and included the perception that their physical and cognitive ability had improved (e.g. reaction time, hand eye coordination, skill learning and movement ability), affective responses (e.g. felt the benefits to the body, enjoyed it and was hooked, increase in self-efficacy, feeling comfortable) and social benefits (e.g. meeting new people). For example, having the opportunity to meet new people and play with similar and likeminded people created an environment where individuals felt comfortable and could have a fun and enjoyable experience. Consequently, due to the environment created, they were able to play in a way which facilitated beliefs that they had improved their physical and cognitive ability as well as feeling the benefits to the body, which contributed to enjoyment, being hooked and increased confidence.

> *'Yeah, I mean I certainly feel as I can hit the badminton shuttlecock now. Um, whereas before when I've had to go, um, I'd miss it an awful lot of times, and my reaction seems a lot better. The speed of reaction, hand eye coordination seems better'* (3.4, M).'*Yeah. I think I'm, uh, a bit fitter and uh, maybe a bit more confident about, uh, you know, uh, playing badminton'* (3.5, M). '*You know, um, and also thinking about the other physical things where we're doing with the knee, going down and practicing that is right. Obviously you've gotta get down to catch it if it's coming down too low. And I'd probably think I'd just do it from here, but now I gotta think a little bit harder. Okay. I might miss it, but at least I'm thinking about where it's gonna be and, and where I've got to be. So I suppose it's a mental thing that's, uh, running through at the same time as the physical'* (3.6, M)
>
> *'First. I mean I came out of each session thinking, oh I've used the body a bit and I'd rather enjoyed that and I'm looking forward to coming back again. Yeah. That was my overall sense And presumably cuz we all turned up again, that was the theming of other people* '(2.6, M).'*Yeah, I think, I think, you know, most of us or, well I can't speak for, but for myself I felt more positive about badminton at the end of the eight weeks than I did at the beginning. You*

know, I felt quite positive at the beginning but I felt better at the end cause we'd been sort of laying around and doing different things '(2.5, M)

Theme 3: Reinforcing and disabling factors: ability and opportunity

Participants frequently discussed ability and opportunity as processes of change (reinforcing and disabling factors). Early positive experiences or lack of fitness and the diversity of the ability in over 60's was seen as either an enabler or disabling factor. When ability was a disabling factor, the opportunity to be able to rest as needed and join back in when ready was important as well as playing those of a similar ability, which meant the game could still be enjoyable. Furthermore, the way the opportunity was provided created a low pressurised environment with the positive changes considered to be due to the opportunity provided where they could play with similar ability, the groups were unformed, the environment being inclusive and supportive, people were at the same level and/or starting together, and autonomy provided. People who were more able also shared the experiences they had observed of others less able in their group with admiration.

''But you could stop if you needed to. Cause there were a couple of ladies who were on our court who got out of breath quite quickly and they would just go and sit down and then join in when they were ready and it worked really' (3.1, M)

'And, and I think that's been one of the nice things about this, you know, I don't think, I wouldn't imagine anybody has felt, you know, embarrassed by their level (2.5, M) *'it's been very inclusive'* (2.6, M). *'It's been very, been very supported, it's environment really. And everybody's probably enjoyed it from that point of view. So, um, yeah, it's, it's, I just wanted to pick on that point about the department'* (2.5, M)

'*I think the good thing about badminton is as long as you are playing somebody of similar ability, you can enjoy the game no matter what ability'.* (1.2, F)

'I think it's just sort of a pretty non pressurised, uh, environment as well. I mean, you come into it, you come into it on the basis that you, you're sort of being assessed for your fitness, which is sort of an individual thing. And then you gradually sort of, uh, melt into the rest of the group as it were, sort of thing. So it's just, it's a sort of an easy way of getting to interact with other people and get to know other people really' (2.5, M) Mm-hmm. <affirmative>. (2.3, F) *'Cause it's not, there's no sort of initial meeting pressure as it were. You know, you, you sort of gradually sort of introduced to the rest of the group in, in a, in a sort of a soft way really. So I think, I think that appeals to a lot of people. It appeals well, it appeals to me, let's put it that way. can't speak for anybody else, but I think it's a sort of, um, it's a, it's a pleasant low pressure way of getting into an environment and a group that's, you know, positive. So I think it's, um, it's got a lot going for it. This kind of, this kind of approach to bringing people into sport, I think is a good thing. And, and, and using the uh, let's say the entree of, well let's see what your physical fitness is to start with and then what you do a programme and then we'll see it at the end. I think that's an appealing, appealing prospect, appealing idea for a lot of people*' (2.5,M).

'Really interesting, I think the principles that sort of, um, made it a successful exercise for us. I think we are all relatively, um, confident people [referring to the people in the group interview], but I think, I think this kind of process enables people who are less confident to move into a group that's not already formed. Because I think that's what puts a lot of people off joining sports clubs. You know, they're, if they're, if they're relatively middle, if they, if they're not particularly sociable types and haven't got a lot of friends or whatever, then it's difficult to just go along to a football club or whatever and say I wanna play football, play your team sort of thing. It's perhaps not a very good example, but I just, the process of moving into a new social environment is quite stressful for a lot of people. So I think coming into or having available to you or explained to you that the, that what is available is, is is basically an unformed group. So everybody's in the same boat, everybody's just sort of coming along with their own agendas or whatever requirements or motives and, and um, and therefore everybody's in the same boat and everybody sort of has a chance to get into it more easily, if you see what I mean. It's, it's, it's, it's, it's uh, you know, I think one of the benefits is, as you say, you know, the social grouping that you get, the, the interactions is pleasant, pleasant enough, you know, to, to, to meet new people and all that sort of thing. Um, but in the real world as it were though, moving into those kind of new social settings is more, more difficult. So I think this is an easy way of doing that because the groups aren't formed and it's, it's something new for everybody. Well, apart from this little group here, we do go walking together. But, but generally speaking I think it's a sort of, um, easy opportunity to get into something without having the, the sort of stress involved' (2.5, M)

Hopes For the Future

Two common themes were identified related to hopes following the programme 1: Want to continue with likeminded people, 2. Badminton infrastructure.

Theme 1: Desire to continue with likeminded people

All groups reported enjoying the experience, felt they were in a better position with playing than at the start and wanted to continue with likeminded people. They felt that continuing with likeminded people provided an environment they could be comfortable in practicing or pushing themselves further as well as being able to accommodate each other. There were some differences in what they wanted to achieve from these further sessions, some wanted more informal sessions whilst others wanted a longer duration programme which focused specifically on playing a game including technical coaching and scoring. This was prominent in individuals who reported in the programme evaluation the need for more direct specific technical instruction (group 2) and for those in group 1 and 3 who had no prior playing experiences but felt they had got to the stage to start to play a game.

'I don't think I could go in and join an existing badminton group cuz I feel, I feel as though I wouldn't be up to speed. No. But I would definitely like to go somewhere where I would feel comfortable in practicing. So rather than a game per se… I would just like to just hit it and, and do' (1.6, F)

> *'I think for me, other people might not agree with this, I would like it to be 10 weeks. So we got to the stage, we got to at the end of the eight weeks and then the next two weeks we could really play, you know, get to know the rules really well in* ' (3.3, F). *'the actual rules. I mean, someone like me have never played it, you know, totally never played it. Uh, I even at the end, I really didn't know the rules. Uh, yeah' (*3.1, M).

Theme 2: Badminton infrastructure

Participants, particularly of group 2, discussed the infrastructure of badminton as a sport targeted for older adults in comparison to tennis or golf. They discussed the challenges of having to find a person to play with, age-appropriate leagues, having to book a court, knowing where to play and more. They discussed how in tennis and golf this infrastructure with a social network exists. They reported a hope that a badminton infrastructure could be developed like comparative sports.

> *'…You don't seem to get the same badminton club network do you, as you do tennis clubs for example, you, you know, there's, there isn't a sort of, uh, badminton club circuit Is that really that you could say? I mean, Badminton tends to be, um, using leisure, leisure club facilities or something like that, you know, and, and maybe a a a badminton group has access to some facilities at the leisure center or something like that. But they don't, they don't actually have their own facilities. They don't actually have their badminton club facilities, you know, I mean we always, we, I been played, I've played quite a reasonable amount of badminton, I suppose 30 or 40 games I suppose, something like that. And um, we always say, you know, oh we must go down to [Place] and you know, get some sort of masterclass or something like that, you know, to improve our game. I mean, it, it probably would make much difference to us at our age. But I mean it's, it's just, I mean that the only thing you can think of, you know, is the only thing you can pinpoint in badminton…, is Milton Keens is the national center, you know, and he watched the, I mean we went to the um, we went to the national championship so, um, two or three weeks ago at uh, at the arena in Birmingham, the badminton championships. You know, try and pick up a few tips. But I think apart from, um, apart from things like that, there isn't actually what, I don't know, well maybe there is, but it's just, I'm not aware of it. But I, there doesn't seem to be a kind of a, a network of clubs or, um, you' (2,5,M). 'You mean a support that has a social surround?'(2.6, M). 'An infrastructure, I suppose..what would you do?...how would you align yourself to a, a club? Where would you go? What would you, how would you kick off? You know' (2.5, M).*

DISCUSSION

PA promotion is at the foundation of public health strategy to promote healthy ageing (Beard & Bloom, 2015; Cruz-Jentoft et al., 2019), where age-appropriate group-based exercise, using sport as a vehicle, may be effective for improving physical and psychosocial health (Duncan et al., 2022; Gayman et al., 2017). Whilst those that continue to play sport across the life course typically elicit healthier ageing trajectories (Oliveira et al., 2023), sport as a PA opportunity for older adults is not

widely explored and research focused on developing and evaluating the efficacy of age-appropriate sports interventions is sparse (Jenkin et al., 2017). The present study addresses this gap in the literature and evaluated the effect of STS, an introductory 8-week badminton intervention designed specifically for older adults, on functional fitness, wellbeing and badminton specific skill. Furthermore, thematic analysis of focus groups was used to understand the lived experiences of undertaking the STS. Results of the present study demonstrate that upper body strength, aerobic capacity, coincidence anticipation time and short serve performance were improved in individuals that completed the STS intervention. As such, these data infer that STS is effective in improving physical and cognitive facets important for healthy ageing, where STS may provide an initial platform to elicit broader and more pronounced healthy ageing benefits through sustained badminton engagement. STS is the first badminton specific intervention designed for older adults, where the age-appropriate opportunity to participate in badminton, with likeminded people of similar ability were primary motivators to engagement. The programme was perceived by participants as appropriate and well-structured for the target population, with participants perceiving improved physical and cognitive ability, affective responses, social benefits and increased self-efficacy following completion. Despite a willingness to continue playing badminton, participants indicated that further coaching on technical and tactical elements would facilitate longer term engagement but also highlighted the lack of badminton infrastructure as a primary barrier.

Effect of STS on Physical & Cognitive Function

Studies examining the health benefits of recreational badminton are sparse and the available literature specific to children and young adults (Cabello-Manrique et al., 2022). Results of the present study indicate for the first time that the physiological, biomechanical and cognitive demand of recreational badminton can be harnessed to promote healthy ageing by enhancing physical and cognitive function. Furthermore, such benefits can be recognised in a reasonably short time frame, with only a single weekly session. These findings provide support more broadly for the value of engaging or re-engaging with sport as an opportunity for promoting healthy ageing and extend the evidence base which is largely specific to soccer (Duncan et al., 2022).

Participants that completed STS increased upper body strength, aerobic capacity and coincidence anticipation time, with such facets of physical and cognitive performance underpinning the completion of activities of daily living (ADL) and differentiating between capability of completing advanced and basic ADL (Demekong et al., 2022). Moreover, muscular strength, aerobic capacity and reaction time are direct markers of health, where an age-related reduction in these components is linked to morbidity, increased fall risk and all-cause mortality (Fung et al., 2020; Newman et al., 2006; Pacifico et al., 2020; Wang et al., 2016). Such findings should be contextualised with respect to the purpose of STS, which is designed to be an age-appropriate introduction-reintroduction to badminton to provide impetus for longer term badminton engagement in which there is the potential for further health benefit. For example, data from the Copenhagen City Heart Study indicated that engagement with badminton increased life expectancy by 6.2 yrs compared to a sedentary group (Schnohr et al., 2018). However, to realise the wider potential of STS, these findings need be contextualised with respect to barriers and enablers to initial and sustained engagement.

Engagement & Sustainability

Although particularly lacking for sport, there is a wealth of evidence supporting the beneficial effects of well-designed exercise or PA interventions for promoting healthy ageing (Chou et al., 2012; Vogel et al., 2009b). Whilst the benefits of PA are without question, the wider and sustained impact of such interventions are limited by their effectiveness to incite behaviour change. As such, focus groups were used to understand barriers and enablers to engagement with STS and longer-term engagement with badminton upon completion of the programme. Whilst there are several theories used to explore behaviour change in a PA context, the Behaviour Change Wheel (BCW) provides a synthesis of many previously established frameworks (Michie et al., 2011). Central to the BCW is the Capabilities, Opportunities, Motivations, Behaviour (COM-B) model (Michie et al., 2011) which is recognised by the National Institute for Health & Care Excellence as a key framework for understanding and supporting behaviour change (NICE, 2014). The measured effects and long-term impact of STS is based on developing Capabilities, Opportunities and Motivation across the different levels of the BCW.

The small number of studies that have evaluated the effects of older adults engaging or reengaging in sport for promoting facets of healthy ageing typically focus on the impact of match-play (Arnold et al., 2015; Duncan et al., 2022; Reddy et al., 2017). Whilst match-play may be adapted to better suit the capability of the population and to mitigate injury risk (e.g. walking football) (Arnold et al., 2015), a lack of perceived capability and self-efficacy are commonly cited barriers and enablers respectively to healthy PA behaviours (Gray et al., 2016b; Lees et al., 2005) and may be specific barriers for engagement in age-appropriate sport which is match-play focused given then need for some degree of technical skill competency. There is a distinct lack of evidence evaluating the impact of interventions designed to introduce/reintroduce older adults into sport, where the focus is on developing competency for sustained engagement. For some participants engagement in STS was driven by positive experiences of previously playing badminton or other racquet sports, where theory suggest that if such experiences are associated with positive perceived affective responses, this can be a driver for behaviour (Brand & Cheval, 2019). STS provided enablement, offering a physical opportunity to engage in badminton and provided training that developed physical and psychological capability. This in combination with demonstrated affective responses during the sessions, where evidence suggests that pleasure or displeasure of PA and exercise experiences can influence subsequent PA behaviour (Ekkekakis, 2017), meaning that STS may provide an important basis for longer term behaviour change.

Data from the present study further indicate that STS was effective for improving self-efficacy. Self- efficacy has been shown to be an important driver to sustained healthy PA behaviours for older adults (McAuley et al., 2003). The increased self-efficacy can in part be explained by improved perception of capability and positive affective responses, where according to Bandura (Bandura et al., 1997), positive task performance experience and physiological feedback are important influences of self-efficacy. In addition, thematic analysis identified several other factors linked to motivation that likely influenced engagement in STS and indicate that the programme may be useful to provide a platform for long-term behaviour change. These factors can be linked to basic psychological needs that form part of self-determination theory (SDT) (Teixeira et al., 2012), which has been used as a model for behaviour change in a PA context (Fortier et al., 2007). Primary themes underpinning

engagement were the perception of participating with likeminded people of similar ability and psychosocial benefit, where perceptions of personal connection (relatedness) in an empathetic and positive environment is a key driver of behaviour (Teixeira et al., 2012). In support, previous work indicates that social capital relates to objectively measured PA levels in older adults (Ho et al., 2018). Furthermore, positive coach perceptions, the perception of an optimally challenging task, and the option to select differentiated tasks to match perceived capability where themes identified by the intervention group which link to the basic psychological needs of competence and autonomy outlined in the SDT (Teixeira et al., 2012), cumulatively resulting in a positively engaging environment for participation.

In accordance with the transtheoretical model of behaviour change that purposes PA behaviours can be mapped to a cycle of six phases (Prochaska & Velicer, 1997), STS may be an effective tool in aiding the transition of individuals in the 'Preparation' phase to the 'Action' phase. However, participants that completed the intervention perceived barriers to sustained engagement with badminton, which may limit the later transition to 'Maintenance' which is typically recognised after six months of sustained behaviour (Pekmezi et al., 2010). Of note, a lack of badminton infrastructure was identified, where more specifically participants outlined opportunity and capability barriers such as finding likeminded people to play with, age-appropriate leagues, knowing where to play, and understanding how to book a court. Although STS was effective for improving competency and self-efficacy for badminton, participants still perceived these as barriers to engagement in already established community-based badminton initiatives. To overcome these issues, providing physical opportunity for the group formed following completion of STS to continue engaging with badminton may be beneficial. Furthermore, participants identified a need to now focus further on developing technical and tactical knowledge of badminton, where extending STS, or development of an intermediate programme focusing on these elements, may evoke further increased perception of competency and self-efficacy needed for engagement in community-based programmes.

Programme Evaluation

As per the principles by which STS was designed, participants perceived that the programme was appropriate for the target age group and for those with different levels of physical and badminton ability, that sessions were well structured, and that progression occurred at an appropriate rate. Participants outlined the importance of sessions being facilitated by physically and interpersonally skilled coach that recognises the needs of the older adult population, which is in line with previous work suggesting instructors' characteristics have influence participants' attendance to exercise classes (Hawley-Hague et al., 2014). Participants also made suggestions for how STS may be improved. The inclusive nature of the intervention was based on differentiating planned tasks by ability, this was typically achieved by manipulating the challenge on each court and affording autonomy to participants in selecting the level of difficulty. After explanation and demonstration, participants were able to choose the task that best suited their perceived capability. Evidence shows that autonomy is important for developing motivation (Bandura et al., 1997), and the value of this approach was also recognised by participants in the present study. However, this resulted in the formation of 'groups' and participants indicated more overt direction to circulate between groups may have been beneficial. Furthermore, groups identified that more explicit information regarding the broader purpose of the tasks and further focus on coaching technique would be useful. Some of these potential areas for development can in part be attributed to the size of the group, length of the session and poor acoustics in the room which were identified by participants. Where space allows, future delivery of STS should consider limiting participant number to four individuals per court.

Limitations & Future Direction

Despite the study offering important new insight into the efficacy of a badminton specific intervention designed to promote healthy ageing, it is not without limitation. Initially, given participant's availability to be able to commit to completing the 8-week group-based intervention, a quasi-experimental approach was employed rather than random group allocation. However, whilst randomised control trials are more robust, statistical analysis of the data from the final sample revealed that the groups used in the study were matched for age, body composition and baseline functional fitness. Furthermore, measures of cognitive function were specific to coincidence

anticipation time, whilst this is relevant to badminton and is important to every day cognitive function, the study did not consider the impact of STS on other measures of cognition, such as executive function, that has been shown to deteriorate with increasing age (Murman, 2015). Furthermore, coincidence anticipation time recorded by swinging a badminton racquet provided a sport specific assessment which was deemed appropriate for the intervention group, but the results may not be directly comparable to the button press method used by the control group. Additionally, exploring further health measures such as blood pressure responses, blood glucose, and heart rate variability, as examples, would also provide further insight into the potential health effects of STS. In addition, understanding the longer-term impact of STS should be an important focus of future work to provide insight into the time course of effects and the longer-term engagement in badminton following completion of STS. Furthermore, the intensity of the sessions was not measured, were objective assessment of perceived effort and physiological demand would help to refine the programme, with understanding the variation in effort between individuals, and would help in providing a basis for comparison to other activities. Given the relatively small sample size, it was not possible to evaluate the impact of the intervention on those with low physical and cognitive function, where the effects may be greater in magnitude and extend to other measures. Finally, whilst focus groups enabled interactions to generate experiences within the group, unique individual beliefs may not have been voiced using this procedure. If time would have allowed, it would have been beneficial to have offered those who didn't attend the focus group discussions, an individual interview to capture their unique experiences. Future work understanding the impact of coach behaviours on the delivery of STS and the efficacy of designing a follow-on programme should also be considered to enhance the broader potential of badminton as a tool to promote healthy ageing.

Conclusion

STS may offer a framework to promote engagement/reengagement with badminton, which as per the results of the present study provides a vehicle to promote healthy ageing. Specifically, STS was effective for increasing upper body strength, aerobic capacity, coincidence anticipation time, short serve performance and self-efficacy for exercise. These benefits to physical and cognitive

function were corroborated by an increased in perceived ability as derived from thematic analysis of focus groups. The STS was an enabler to participation in badminton, where the age-appropriate opportunity to participate, with likeminded people of similar ability were primary motivators and where the reported increase in self-efficacy for exercise may be an important driver to sustaining behaviour. Participants indicated that the intervention was appropriate and well-structured for the target population and made suggestions which may be useful to improve implementation of the programme in the future. In light of a lack of direct evidence, the results of the present study support the application of introducing older adults to sports coaching for promoting healthy ageing. However, despite the specific benefits of STS and a willingness to continue playing badminton, strategies including future programmes focusing on coaching technical and tactical elements as well as strategies to overcome issues with badminton infrastructure are needed to promote long term engagement. Consideration of these factors from a whole systems perspective is needed to increase and promote sustained engagement with sport as an opportunity for promoting healthy ageing.

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FIGURES

Figure 1. Overview of Methodological Approach

Figure 2. The effect of Shuttle Time for Seniors on Functional Fitness [A. Chair Stand; B. Arm Curls; C. Chair Sit & Reach Right; D. Chair Sit & Reach Left; E. Back Scratch Left; F. Back Scratch Right; G. TUG; H. Hand Grip; I. Normal Gait Speed; J. 6MWT; K. Short Serve Test; Centre line represents mean±S.E.M. N>18 for control and N>21 for intervention groups; * P<0.05]

Figure 3. The effect of Shuttle Time for Seniors on coincidence anticipation time [A. Constant Error at 3mph; B. Variable Error at 3mph; C. Absolute Error at 3mph; D. Constant Error at 8mph; E. Variable Error at 8mph; F. Absolute Error at 8mph; Centre line represents mean±S.E.M. N>18 for control and N>21 for intervention groups; * P<0.05]

Figure 4. The effect of Shuttle Time for Seniors on Self-Efficacy for Exercise (A), Wellbeing (B) and Perceived benefits and barriers to exercise (C) [Centre line represents mean±S.E.M. N>18 for control and N>21 for intervention groups; * P<0.05].

Figure 5. Summary of the lived experiences of participation in Shuttle Time for Seniors where qualitative analysis identified themes related to interests and expectations of the programme, experience of the programme, and sustainability of behaviour and hopes for the future.

1 **TABLES**

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Table 1. Sample Characteristics

	Control	Intervention
N =	20 (6F)	23 (8F)
Age (yrs.)	70.2±1.5	69.4±1.4
Height (cm)	168.7±1.9	172.2±1.9

F = female

3

4

Table 2. Intervention Effects of Measures of Body Composition

	Control		Intervention	
	Pre	Post	Pre	Post
Body mass (kg)	74.8±3.3	74.0±3.3	79.1±3.0	78.9±3.1
BMI (kg/m^2)	26.0±0.8	25.8±0.8	26.6±0.8	26.4±0.8
% Muscle Mass	51.8±2.5	51.7±2.5	54.9±2.2	54.2±2.2
% Fat Mass	27.0±1.5	26.4±1.4	27.2±1.6	27.4±1.5

Data represented as mean±S.E.M; n=20 and 23 for control and intervention respectively

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