Title: Tennis for physical health; acute age- and sex-based physiological responses to Cardio tennis®.

Running title: Demands of Cardio tennis®.

Keywords: Fitness, blood pressure, tennis, health, cardiovascular load

ABSTRACT

This study described physiological and perceptual responses to Cardio tennis® for 'younger' and 'older' adult populations of both sex's for health-related outcomes. Thirty-one active participants, each with prior recreational tennis experience (~2 years) (8 younger and 8 older males, and 7 younger and 8 older females) performed preliminary testing and a 50-min instructor-led Cardio tennis® session. Cardio tennis® is a conditioning-based tennis program comprised of warm-up movements, drill-based exercises (set movement and hitting games) and competitive play scenarios. Participants performed the 20-m shuttle run test to determine maximal heart rate (HR) during preliminary testing. Before, after and 30-min post Cardio tennis® session, HR, blood pressure (BP), Rate Pressure Product (RPP) and capillary blood lactate and glucose were determined. Further, HR and pedometer-derived step counts were measured throughout, while the session was filmed and coded for technical skill. Following the session, ratings of perceived exertion (RPE), enjoyment and challenge were obtained. HR, systolic BP and RPP were significantly increased by Cardio tennis® ($p<0.05$), though returned to pre-exercise levels 30-min after ($p>0.05$). HR and BP did not differ between groups pre- or 30-min post-exercise ($p>0.05$); however, were lower in younger males during and higher in younger females post-session ($p<0.05$). Lactate and glucose concentrations were increased in all groups ($p<0.05$), with lactate highest in male groups ($p<0.05$), without differences in glucose between groups ($p>0.05$). Stroke and step counts were not different between groups ($p>0.05$). RPE and perceived challenge were lowest in the younger male group compared to all other groups ($p<0.05$). Cardio tennis® presents as an effective stimulus to invoke sufficient cardiovascular and metabolic load to benefit health and fitness, though age-and sex-based responses should be considered in prescription.

KEYWORDS: Fitness, blood pressure, tennis, health, cardiovascular

INTRODUCTION

There is growing evidence suggesting inactivity and sedentary lifestyles exacerbate the cardiovascular and metabolic risk factors predictive of chronic disease development in the general population (2, 17). Conversely, engagement in regular exercise promotes improved health-based outcomes related to the aforementioned factors and reduces chronic disease risk classification (1, 12, 25). Whilst aerobic and resistance modes are traditionally used for exercise prescription (5); recent research has focused on the role of sport, particularly modified football via small-sided games, to provide adequate acute and chronic doses with the aim of improving physical health in many sedentary populations (20, 27). Within this context, minimal research evidence exists quantifying the physiological responses for other sports that may also impart health and fitness benefits for the general public. Although tennis has been proposed as an exercise mode that delivers improved fitness (21, 26), few studies exist on non-competitive populations to provide an understanding of the prescriptive benefits of tennis for physical health.

Recently, a community-focused participation program, named Cardio tennis®, has been implemented to provide a group-based, non-competitive tennis program designed to improve cardiovascular and metabolic health along with tennis-specific skills. Whilst the potential health benefits of a community-focused, tennis-based exercise program is of interest, to date there still remains the question of whether the specific physiological demands of Cardio tennis® are sufficient to allow appropriate exercise prescription in comparison to American College of Sports Medicine (ACSM) guidelines of exercise prescription (8).

Competitive tennis is known to induce prolonged and substantial physiological demands (6, 18), potentially explaining the well-developed fitness capacities of professional players (19, 29). Of greater relevance to the general community, regular (recreational) tennis training over 6-weeks was reported to improve cardiovascular fitness and body composition in middle-aged recreational players (7). Such findings may explain the noted higher aerobic capacity and strength, alongside lower fat mass observed in veteran tennis players compared to inactive control groups (21). Accordingly, indirect evidence exists to suggest the engagement in regular bouts of tennis training may confer physiological health-related benefits (11, 26). However, exercise prescription requires an understanding of the demands of the bout to ensure not only the delivery of an appropriate exercise dose, but also avoidance of potential contraindications (26). Furthermore, constraints preventing engagement in the prescription of sport-based exercise programs include the competitive nature of a skill-based sport and the need for sports-specific aptitude; potentially restricting participant engagement and hindering participation and resultant health benefits (30).

Recently, Cardio tennis® programs have been implemented as a mode to promote engagement in tennis for improved health and fitness outcomes. Cardio tennis® involves group-based, on-court programs set to music and mixing a range of socially inclusive physical activities, technical skill development and point play. Whilst Cardio tennis® may represent a non-competitive, social means of physical activity, quantification of the physiological demands to allow appropriate dose prescription is required. Further, the respective responses and contraindications for differing age or sex-based populations also remain unknown. Similarly, whilst Cardio tennis® is currently used by each of the subject groups, specific research based information for coaches on the prescription of Cardio tennis® as a training stimulus is lacking. An understanding of these variables is fundamental for a health-driven mode of exercise prescription. Accordingly, the primary purpose of the current study was to describe the physiological and perceptual responses to Cardio tennis®; and secondarily, compare these responses between ‘younger’ and ‘older’ adult populations of both sex’s within the context of ACSM guidelines of exercise prescription (8). With the previously described health benefits associated with tennis, the aerobic-based Cardio tennis® is hypothesized to produce similar positive physiological effects in accordance with ACSM standards for each respective subject population.

METHODS

Experimental Approach to the Problem

This study is the first to examine the physiological effects of a Cardio tennis® session in recreationally active men and women. To achieve this, the study followed a between-group (age and sex) comparison design, detailing the physiological changes throughout a Cardio tennis® session. We tested the hypothesis that a Cardio tennis® session would be of sufficient physiological stress to elicit beneficial adaptations in healthy, active population groups. In order to establish and therefore compare cardiovascular responses to industry guidelines, heart rate, blood pressure and capillary blood lactate and glucose were measured before and after the Cardio tennis® session. Further, heart rate and pedometer-derived step counts were measured throughout, while the session was filmed and later coded for technical skill outcomes. Following each session, a rating of perceived exertion (RPE) and a perceived rating of ‘enjoyment’ and ‘physical challenge’ were also obtained. Time of day for testing was standardized for all participants. Further, participants abstained from alcohol and intense exercise for 24h prior to, and caffeine 3h before each session. All fluid, food and physical activity were standardized prior to each testing session and participants noted consumption and activity in provided diaries for inspection by the research team. During the Cardio tennis® session, all participants were restricted to 400mL of water to be consumed *ad libitum*.

Subjects

A total of 31 active volunteers participated in this study. Each participant had prior recreational tennis experience (1-2 sessions a week, ~2 years), but did not participate in any formal competitive match-play. Descriptive characteristics are presented in Table 1, and although groups were not matched for fitness, they were of similar level of recreational tennis engagement. Specifically, participants included 8 'younger' (20-30y) and 8 'older' adult males (30-45y), and 8 'younger' and 7 'older' adult females. Participant age ranges were based on suitability and appropriateness to undertake potentially vigorous exercise (<50y and free of disease), and were a likely population group who would undertake Cardio tennis® based on market surveys and feedback conducted by the organization responsible for Cardio tennis®. All current participants were physically active, engaging in 2-3-exercise session per week in the last 6 months. Further, all had prior familiarity with the sport of tennis, either at a social or competitive level. All experimentation was approved by and followed guidelines of the University Ethics in Human Research Committee. All participants provided written and verbal informed consent following full explanation of all procedures.

Procedures

Following a familiarization session (~2 h) on the previous day, participants attended an initial morning testing session (06:00-08:00) following an overnight 10h fast at which stature (Customised Stadiometer, Bathurst, Australia) and mass (MS3200, Charder Electronic, Taichung Hesin, Taiwan) were measured to calculate Body Mass Index; followed by collection of a fingertip capillary blood sample to determine fasting blood glucose (Accu-Chek Advantage, Sydney, Australia). Further, participants also performed the 20-m Multi-stage Shuttle Run Test (Australian Sports Commission, Canberra, Australia) using set-paced audio prompts until volitional exhaustion to determine maximal heart rate.

At a separate session, and within respective age- and sex-based groups, participants performed an instructor-led 50-min Cardio tennis® session on an indoor plexi-cushion tennis court in environmental conditions of 15±3ºC and 40±8% relative humidity. The same instructor supervised all four groups to ensure standardized delivery and timing of the same session. The Cardio tennis® session was accompanied by music (140-160bpm) from a standardized music track-list and consisted of three components; warm-up movements, drill-based exercises (set movement and hitting games) and competitive play scenarios, each using customized low compression tennis balls (Wilson, Chicago, Illinois, USA). The warm-up consisted of footwork drills, general tennis movement patterns, and small-sided tennis movement games. The drill-based training section consisted of small-sided tennis games, down-the-line and cross-court hitting drills in pairs on either end of the court and drills involving rotating through various tennis-specific stations. Further, a final component of each session was doubles-based point play with losers moving off court for planned footwork drills. The entire session was monitored closely by the instructor for maintenance of the movement and striking of the ball. Wherever a mistake was made a new tennis ball was played into the court to seamlessly continue the drill. As a result, Cardio tennis® sessions require limited skill level, as the aim is to improve cardiovascular fitness and coordination. Furthermore, sessions are well controlled by the present instructor to ensure that each individual's tennis skills were accommodated for.

To determine cardiovascular load, heart rate (Suunto Memory Belt, Suunto Oy, Vantaa, Finland) was continuously recorded at 5s intervals for the entirety and 30-min following the session and downloaded to calculate mean and peak heart rate (Suunto Training Manager, Suunto Oy, Vantaa, Finland). Manual blood pressure was obtained with an aneroid sphygmomanometer and cuff (Welch-Allyn, North Carolina, USA) at rest, at a break at 30-min during and immediately and 30-min post-session. Further, the rate pressure product (RPP) was calculated at the aforementioned time points based on the time aligned measures of systolic blood pressure and heart rate to indirectly determine cardiovascular stress representative of myocardial oxygen cost (13). To determine metabolic responses, a 20μl sample of capillary blood was obtained from an earlobe to measure glucose (Accu-Chek Advantage, Sydney, Australia) and lactate (Lactate Plus, Waltham, USA) concentrations before, after and 30-min following the session. Following each Cardio tennis® session, participants provided a measure of RPE (Borg C-20) and perceived 'enjoyment' ("how enjoyable") and 'challenge' ("how challenging") based on a Likert scale of 0 – 10 (with 0= not at all and 10= very high). During the session, participants wore a pedometer (Digital Pedometer, Carta-Sport, China) affixed to the waistband of clothing medial to the anterior superior spine of the iliac crest to measure the number of steps undertaken. Furthermore, sessions were filmed by a digital video camera (DSR-PDX10P, Sony, Japan), located 8-m above and 6-m behind the baseline. Footage was downloaded and viewed later to notate for total stroke count, total hitting duration and unforced error rates. Coding was performed using customised software (The Tennis Analyst, V4.05.284, Fair Play, Australia) by an analyst with a co-efficient of variation <2%.

Statistical Analyses

A repeated measures two-way ANOVA (condition x time) was performed to determine differences ($p<0.05$) in physiological and perceptual responses between respective age- and sex-based groups. Further, Tukeys' post-hoc t tests were conducted to determine differences where main effects were evident.

RESULTS

Based on descriptive characteristics in Table 1, both respective 'older' groups were significantly older and had lower maximal heart rates than their 'younger' counterparts; while both female groups were of significantly lower body mass and stature than male counterparts ($p<0.05$). The younger male group had a significantly higher 20-m shuttle run test score than all other groups ($p<0.05$), while there were no differences in fasting glucose concentrations between groups ($p>0.05$).

Mean heart rates were significantly higher in younger females ($p<0.05$), without differences ($p>0.05$) between other groups (145±10, 152±9, 163±5 and 151±10bpm for younger and older males and younger and older females, respectively). Similarly, peak heart rates were significantly higher in younger females ($p<0.05$), without differences ($p>0.05$) between other groups (176±10, 178±9, 184±5 and 176±11 for younger and older males and younger and older females, respectively). Heart rate (absolute and as a % of maximum), systolic blood pressure and RPP were all significantly increased during and immediately following Cardio tennis® ($p<0.05$), though had returned to pre-exercise levels 30-min post-exercise ($p>0.05$; Table 2). Heart rate (absolute or % of maximum) did not differ between groups at rest or 30-min post exercise ($p>0.05$); however, was significantly lower in the younger males during and significantly higher in younger females at the end of the session ($p<0.05$). Systolic blood pressure was not different between groups before, during or 30-min post exercise ($p>0.05$), although was significantly lower post-exercise in the older females ($p<0.05$). Diastolic blood pressure did not increase in response to exercise and was not different between groups ($p>0.05$). As above, RPP did not differ between groups before or 30-min post-exercise ($p>0.05$); however, was significantly lower in young males during and lower in older females after the session compared to other groups ($p<0.05$; Table 2)

Blood lactate and glucose were significantly increased immediately following Cardio tennis® ($p<0.05$), but had returned to pre-exercise levels 30-min post-exercise ($p>0.05$; Table 2). Blood lactate did not differ between groups at rest or 30-min post exercise, though was significantly higher in both male groups compared to their age-matched female counterparts ($p<0.05$; Table 2). Blood glucose was significantly higher pre-exercise in the younger female compared to other groups ($p<0.05$), but did not differ between groups at any other time point following exercise ($p>0.05$).

Insert Table 1 and 2 around here

Step count, total stroke count and total hitting duration did not differ between groups ($p>0.05$; Table 3), although the error rate for younger females was significantly higher than for all other groups ($p<0.05$; Table 3). Post-session RPE was significantly lower for the younger male group than all other groups ($p<0.05$). Similarly, both younger groups rated the session as less challenging than their sex-matched older counterparts ($p<0.05$; Table 3), though all groups rated the session as sufficiently challenging. Finally, despite all groups rating the session as highly enjoyable, both younger groups rated a lower enjoyment than their sex-matched older counterparts ($p<0.05$).

Insert Table 3 around here

DISCUSSION

The quantification of the physiological demands of an exercise bout assists in an understanding of the dose-specific responses to aid appropriate exercise prescription and ensure avoidance of exercise-induced contraindications. Accordingly, Cardio tennis® sessions present as a moderate to vigorous exercise stimuli for the general public, inclusive of both male and female groups in both age ranges. Specifically, mean heart rates were elevated above 75-80% of maximum in all groups, with blood pressure increasing to >160/80 mmHg, RPP >200bpm$^{-1}\cdot$mm (x10^{2}), lactate concentrations >4.0 mmol$\cdot$L^{-1}, glucose concentrations >6.0 mmol$\cdot$L^{-1}, RPE values >14 and over 5000 steps undertaken in a 50-min session. Consequently, Cardio tennis® can be viewed as providing an effective exercise stimulus to incur cardiovascular and metabolic loads appropriate for fitness training as outlined by ACSM standards (8). As such, younger participants may use Cardio tennis® sessions to compliment current physical training or provide a cross-training cardiovascular stimulus. Furthermore, older populations or subjects of lower cardiovascular fitness may utilize Cardio tennis® as an adequate cardiovascular and metabolic stimulus to provide health benefits. However, the same session resulted in lowered physiological and perceptual responses for the younger male group, whilst intermittently elevated the cardiovascular response of the older male group to above 85% of maximum. Accordingly, some care should be taken in prescribing Cardio tennis® to ensure sessions are individualized as appropriate for all age groups and fitness levels.

One of the main physiological benefits imparted by exercise relates to improved cardiovascular fitness from increased blood volume, improved myocardial contractility and increased oxygen uptake capacity (4, 5, 9). Competitive tennis is known to result in mean heart rate responses of 140-170bpm and oxygen uptake of 20-45$ml \cdot kg^{-1} \cdot min^{-1}$ (6, 18, 19). Such demands are likely to then result in significant improvements in cardiovascular capacity with continued regular training exposure (7, 19). The heart rate, blood pressure and RPP responses noted in the current Cardio tennis® session further highlight the significant cardiovascular demands of this form of exercise for a range of ages and sex's (13). Whilst no data exists from a training or cross-mode comparison perspective, comparative to previous research of aerobic cycling, full-body resistance and concurrent exercise modes above 80% maximal heart rate (4, 9); the acute responses here would be deemed a sufficient dose to improve cardiovascular fitness if performed regularly, agreeing with the hypothesis that Cardio tennis® is an effective non-competitive alternative to tennis yet still conforms to industry guidelines (8, 24). However, as for most exercise prescription an individualized approach is recommended, as different age and sex groups exhibited differing responses. In particular, the same Cardio tennis® session resulted in lower heart rate responses in the younger males, especially when expressed as a % of maximum. Given the higher aerobic fitness capacity of this group, it is not surprising that a standardized Cardio tennis® session resulted in a lower relative cardiovascular load. Conversely, for the older male and female groups, the Cardio tennis® session was in the upper limits of what would be deemed appropriate for such a population (>85% heart rate maximum). Furthermore, transient increases in RPP >250 $bpm^{.-1}$mm and systolic blood pressure >160mmHg highlight the potentially vigorous nature of this mode (8, 24). Given the current RPP responses represent a significantly elevated myocardial oxygen cost, such increased stress may not be suitable for diseased or obese populations; highlighting the need for individualized monitoring of exercise-induced responses, particularly in older populations (8, 13). However, current industry guidelines suggest sedentary or recreationally active populations participate in 2-3 vigorous bouts of exercise per week (8, 24), and within reason, Cardio tennis® would seem suitable to meet those demands.

The increasing concerns regarding prevalence rates of obesity and type 2 diabetes are purported to be a consequence of high caloric dietary intake alongside reduced physical activity (3, 10). Consequently, an important facet of exercise is to provide a pathway for glucose disposal, in turn assisting insulin regulation of blood glucose (10, 14). The present Cardio tennis® session resulted in an effective increase and then decrease in blood glucose; further highlighted by the moderate increase in blood lactate indicating anaerobic glycolytic activity. Although both male groups resulted in more pronounced increases in blood lactate, potentially due to a greater active muscle mass, all groups resulted in significant changes to blood glucose. Again, without chronic exposure data it is speculative to suggest the current exercise stimulus may provide long-term glucose regulatory benefits; however, previous research of aerobic exercise training above 75% maximal heart rate for 30-60min over 10-14 weeks reports improved insulin resistance and glucose tolerance in sedentary middle-aged populations (14, 15). Conversely, 6-weeks of tennis training in middle-aged recreational players did not improve blood lipid profiles, despite improved oxidative capacity and anaerobic threshold (7). Regardless, the present study highlights the significant metabolic demand invoked by a Cardio tennis® session for recreationally active males and females, and with prolonged exposure within a training period positive metabolic adaptations may occur.

Community education programs aiming to increase physical activity highlight the importance of daily movement and the notion of accumulating 10000 daily steps as a surrogate measure of physical activity (28). The current study reported no difference between age or sex groups for the number of steps performed during 50-min of Cardio tennis®, though in all groups the total step count was in excess of 50% of the daily recommended volume (28). Unfortunately due to the indoor nature of testing, global positioning satellite measures of external load were not possible, hence step counts were a surrogate measure of the volume of movement derived during Cardio tennis®. Regardless, Cardio tennis® seems an appropriate exercise mode to increase physical activity, resulting in elevated metabolic and cardiovascular responses. Furthermore, the development of technical skill is an obviously important part of the successful engagement in a sports-specific exercise bout such as the present mode. Accordingly, all groups resulted in similar hitting durations and total stroke counts, with over 50% of the time involved in stroke-play and over 100 strokes performed. Comparatively, tournament match play results in only 25-35% of time in stroke-play (19), although total stroke counts may be as a high as 300-400 (16, 29). Given the social and exercise-focused environment of Cardio tennis®, sufficient time allocation and allowance for stroke play seems evident.

RPE for all groups were comparative to other reported exercise modes with similar exercise intensities, including cycle ergometry (22), resistance (4), concurrent (9) and football small sided game (23) modes. Given the reduced heart rate responses for younger males, it is not surprising to observe lower RPE values compared to other groups. Regardless, exercise prescription guidelines suggest doses to improve cardiovascular fitness to be above C-13 or CR-4 of the respective Borg scales (8, 24) and accordingly Cardio tennis® conforms to such recommendations. Not surprisingly, similar results were observed for the perceived challenge of the session; which although deemed to be physically demanding, was perceived to be less demanding in younger than older groups for each sex. Finally, regardless of the effectiveness of the session to deliver a physiological stimulus, it is also worth noting participant enjoyment (30); particularly given the need for regular engagement over time for health benefits. The present findings suggest that participants enjoyed the Cardio tennis® session, though this is not surprising given all had backgrounds in tennis. It remains to be determined whether similar findings would be present in a population without familiarity to tennis. Of further interest, both younger groups rated the enjoyment as lower than respective older groups. Whilst follow up questioning was not conducted, it is speculated that group-based tennis training may provide greater motivation, social interaction and enjoyment for the older as compared to the younger groups.

PRACTICAL APPLICATIONS

Cardio tennis® presents as a stimulus that can effectively invoke sufficient cardiovascular and metabolic stress to elicit beneficial health and fitness outcomes meeting industry guidelines as an appropriate prescriptive form of exercise. Cardio tennis® may be used as an effective cross-training method in which strength and conditioning or fitness coaches can ensure physiological stimulus is maintained along with an increased element of enjoyment. However, caution is advised when prescribing Cardio tennis®, as the same session resulted in lowered physiological and perceptual responses for the younger male group, whilst transiently elevated the cardiovascular responses of the older groups to what would be deemed above recommended intensities for a sedentary population. Regardless, Cardio tennis® provides acute physiological and perceptual demands comparable to other traditional modes of exercise training, though whether this training stimulus confers ongoing health benefits requires further investigation. Finally, the non-competitive and social elements of Cardio tennis® sessions provide enticing environments for cross-training athletic sessions, but in particular for health benefits for the general community.

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