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Original Research Article

The Acute and Chronic Physiological Responses to Pickleball in Middle-Aged and Older Adults

Leslie E. Smith¹, Christina A. Buchanan¹, Lance C. Dalleck¹

¹High Altitude Exercise Physiology Program, Western State Colorado University, Gunnison, CO, USA

Abstract

Purpose: The purpose of this study was (a) to quantify the acute cardiovascular and metabolic responses to Pickleball, and (b) to determine the effectiveness of a 6wk Pickleball intervention at positively modifying cardiometabolic risk factors. **Methods:** Fifteen women and men (mean \pm standard deviation: age, weight, percent body fat, and maximal oxygen uptake = 65.2 ± 8.0 years, 76.3 ± 20.5 kg, 30.3 ± 6.6 %, and 26.2 ± 5.7 mL/kg/min, respectively) completed both a maximal graded exercise test and played a doubles match of Pickleball on non-consecutive days. Cardiovascular and metabolic data were collected via a portable calorimetric measurement system. Additionally, participants completed a 6wk Pickleball intervention (~ 1 /hr sessions performed 3 times/wk). Cardiometabolic risk factors and cardiorespiratory fitness were measured at baseline and post-program. **Results:** Overall average heart rate for Pickleball match play was 108.8 ± 16.7 beats/min, which corresponded to $50.9 \pm 11.2\%$ heart rate reserve. Exercise intensity in metabolic equivalents was 4.1 ± 1.0 which equated to $52.5 \pm 11.3\%$ oxygen uptake reserve. Total energy expenditure for Pickleball was 353.5 ± 85.0 kcal/match. After 6wk of participation in Pickleball there were significant ($p < 0.05$) improvements in the following outcomes: high-density lipoprotein and low density lipoprotein cholesterol, systolic and diastolic blood pressure, and maximal oxygen uptake. **Conclusions:** Findings from the present study support the activity of Pickleball as a feasible alternative to traditional exercise modalities for middle-aged and older adults that elicits metabolic responses within the accepted moderate intensity domain. Moreover, regular participation in Pickleball improves cardiorespiratory fitness and positively modifies key cardiovascular disease risk factors.

Key Words: Group Exercise, Energy Expenditure, Exercise Intensity

Introduction

Pickleball is a game that originated in the 1960s and is a hybrid of badminton, tennis, and table tennis. Pickleball can be played in singles or doubles, and uses solid paddles made of wood or composite materials to hit a perforated polymer ball (similar to a wiffle ball) over a net. It has been reported that Pickleball is one of the fastest growing sports in America especially amongst seniors¹. According to 2013 data from the National Health Interview Survey nearly one-third (30.5%) of U.S. adults do not engage in leisure time physical activity². Physical inactivity is associated with numerous unhealthy conditions, including obesity, hypertension, Type 2 diabetes, and atherosclerotic cardiovascular disease (CVD) and contributes annually to an estimated 250,000 premature deaths³. Older Americans are currently both the least physically active and the most rapidly growing of any age group. For example, prevalence of inactivity in adults 65 to 74 and ≥ 75 years of age are 35.7% and 51.9%, respectively. Moreover, over the next few decades millions of baby boomers will continue to turn 65 years of age⁴. One of the reasons offered for the increased popularity of Pickleball is that it is fun. Given that lack of enjoyment is frequently offered as one of the reasons for physical inactivity in the older adult population, the 'fun factor' associated with Pickleball increases the likelihood of a lifetime pursuit of physical activity. Nevertheless, to our

knowledge there is no research examining the physiological responses to Pickleball.

Understanding the cardiovascular and metabolic responses to exercise is essential for designing safe and effective physical activity and rehabilitation programs. For example, it would be beneficial to understand the metabolic equivalent (MET) value associated with Pickleball. A MET value would allow the quantification of Pickleball exercise intensity as low, moderate, or vigorous in nature, and hence, aid in establishing a safe and effective target workload. The purpose of this study was (a) to quantify the acute cardiovascular and metabolic responses to Pickleball, and (b) to determine the effectiveness of a 6wk Pickleball intervention at positively modifying cardiometabolic risk factors. It was hypothesized that (a) Pickleball would satisfy recommended guidelines for moderate intensity exercise as defined by the American Council on Exercise (ACE) and the American College of Sports Medicine (ACSM), and (b) a Pickleball intervention would favorably modify cardiometabolic risk factors

Methods

Participants

15 middle-aged to older adult men and women (40 to 85 years of age) were recruited from the faculty population of a local university, as well as the surrounding community, via advertisement through the university website, local community

newspaper, and word-of-mouth. Descriptive characteristics of the participants are presented in Table 1. This study was approved by the Institutional

Review Board. Prior to participation each participant provided informed consent.

Table 1. Descriptive characteristics of the participants.

Parameter	Women (N=8)	Men (N=7)	Combined (N=15)
Age (years)	65.3 ± 9.4	65.0 ± 6.6	65.2 ± 8.0
Height (cm)	165.1 ± 7.3	170.0 ± 8.5	167.1 ± 7.9
Weight (kg)	69.8 ± 7.5	84.4 ± 29.8	76.3 ± 20.5
Resting heart rate (beats/min)	61.3 ± 3.8	58.0 ± 3.5	59.9 ± 3.9
Maximal heart rate (beats/min)	154.6 ± 17.6	149.6 ± 16.6	152.5 ± 16.6
Maximal oxygen uptake (mL/kg/min)	25.7 ± 6.6	26.8 ± 4.9	26.2 ± 5.7
Resting oxygen uptake (mL/kg/min)	3.9 ± 0.4	3.9 ± 0.7	3.9 ± 0.5

Values are mean ± SD.

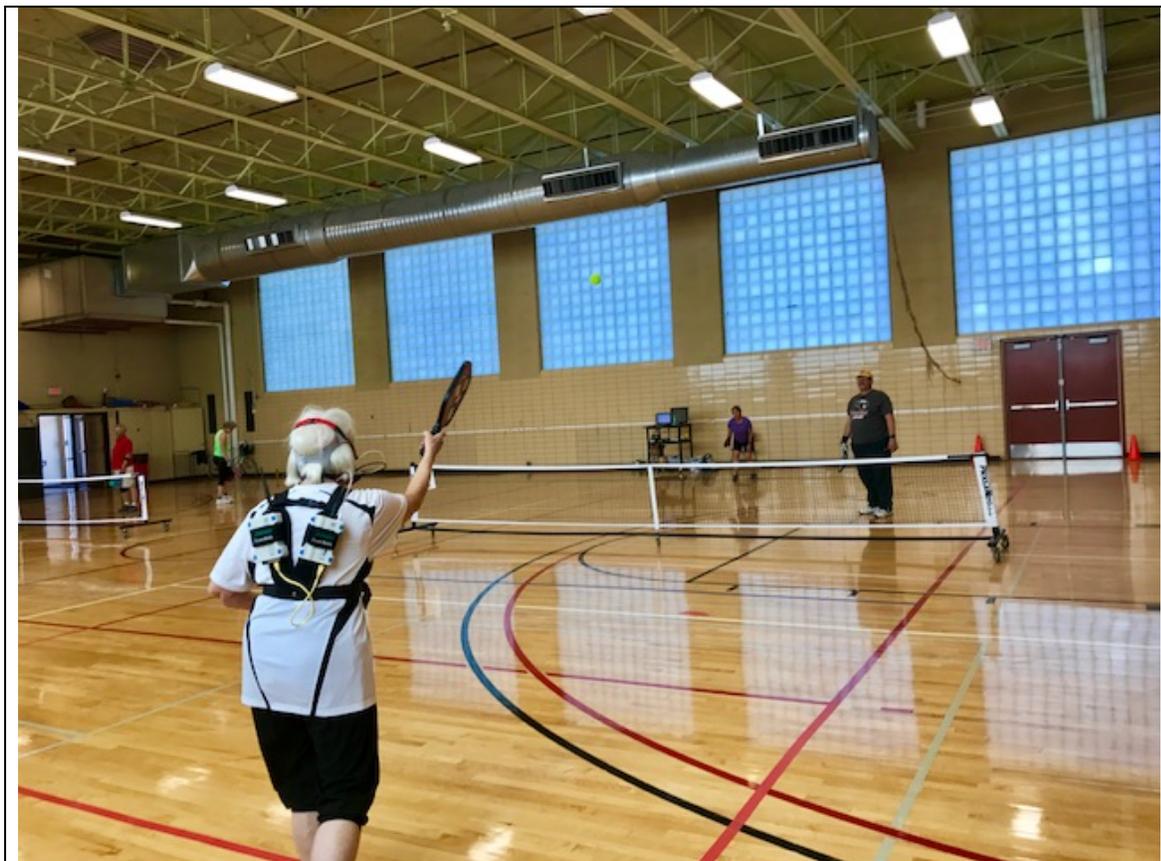


Figure 1. The Oxycon Mobile metabolic system attached to a participant during a Pickleball match.

Experimental Design

Acute responses to Pickleball

To quantify the acute cardiovascular and metabolic responses to Pickleball an Oxycon Mobile portable calorimetric measurement system and Polar F1 heart rate monitor were worn by each participant throughout a single Pickleball doubles match (Figure 1). The average duration of a Pickleball match was ~15min and participants played ~4 doubles matches each day for a total of 1hr.

Chronic responses to Pickleball

At baseline and post-program, participants performed a graded exercise test on a treadmill to determine maximal heart rate (HR) and maximal oxygen uptake (VO_2 max). Resting heart rate was also measured at baseline. Additionally, body composition, fasting blood lipids and blood glucose, waist circumference, and weight were also assessed at baseline and post-program. These measures were obtained to determine the effectiveness of a 6wk Pickleball intervention at positively modifying cardiometabolic risk factors.

Procedures

Anthropometric measurements

All anthropometric measurements were obtained using standardized guidelines⁵. Participants were weighed to the nearest 0.1 kg on a medical grade scale and measured for height to the nearest 0.5 cm using a stadiometer. Percent body fat was determined via skinfold. Waist circumference measurements were obtained using a cloth tape measure with a

spring loaded-handle (Creative Health Products, Ann Arbor, MI). A horizontal measurement was taken at the narrowest point of the torso (below the xiphoid process and above the umbilicus). These measurements were taken until two were within 0.5 mm of each other

Fasting blood lipid and glucose measurement

A fasting blood sample was collected and analyzed for measurement of blood lipid profile and glucose. Participants' hands were washed with soap and rinsed thoroughly with water, then cleaned with alcohol swabs and allowed to dry. Skin was punctured using lancets and a fingerstick sample was collected into heparin-coated 40 μ l capillary tube. Blood was allowed to flow freely from the fingerstick into the capillary tube without milking of the finger. Samples were then dispensed immediately onto commercially available test cassettes for analysis in a Cholestech LDX System (Alere Inc., Waltham, MA) according to strict standardized operating procedures. The LDX Cholestech measured total cholesterol, high-density lipoprotein (HDL) cholesterol, low-density lipoprotein (LDL) cholesterol, triglycerides, and blood glucose in fingerstick blood. A daily optics check was performed on the LDX Cholestech analyzer used for the study.

Resting blood pressure measurement

The procedures for assessment of resting blood pressure outlined elsewhere was followed⁵. Briefly, participants were seated

quietly for 5 minutes in a chair with a back support with feet on the floor and arm supported at heart level. The left arm brachial artery blood pressure was measured using a sphygmomanometer in duplicate and separated by 1 minute. The mean of the two measurements was reported for baseline and post-program values.

Maximal exercise test

After being connected to the Oxycon Mobile system and Polar F1 heart rate monitor, participants rested quietly for 5min in a seated position. The last minute of breath-by-breath and HR data were averaged and considered to be resting metabolic rate (VO_2) and resting HR. On a power treadmill (Powerjog GX200, Maine), a modified Balke protocol was performed with a self-selected walking speed that could be maintained for the duration of the test. Participants were gradually brought to the selected walking speed for the first minute of the test, which was then maintained throughout the duration of the test. The first 1 min of the protocol was performed at 0% grade, thereafter, each minute the treadmill grade was increased by 1% until volitional fatigue was attained. The criteria for attainment of maximal oxygen consumption (VO_{2max}) was two out of three of the following: (1) a plateau ($\Delta VO_2 \leq 150$ mL/min) in VO_2 with increases in workload, (2) maximal respiratory exchange ratio (RER) ≥ 1.1 , and (3) maximal HR within 15 beats/min of the age-predicted maximum ($220 - \text{age}$).

Exercise intensity & metabolic calculations

Individual heart rate reserve (HRR) was determined as the difference between resting and maximal HR values. Percent HRR was calculated by subtracting resting HR from the Pickleball HR response, dividing by HRR, and then multiplying the quotient by 100. Likewise, individual oxygen uptake reserve (VO_{2R}) was determined by the difference between resting and maximum VO_2 values. Percent VO_{2R} was calculated by subtracting resting VO_2 from the Pickleball VO_2 response, dividing by VO_{2R} , and then multiplying the quotient by 100. The metabolic equivalent (MET) for Pickleball exercise was determined by dividing the exercise VO_2 by resting VO_2 for the Pickleball match play (i.e., any warm-up and cool-down metabolic data was omitted in this analysis). Net energy expenditure (kcal/session) for the Pickleball session was calculated by first subtracting the resting metabolic rate (1 MET) from the above-calculated MET equivalent of Pickleball exercise. This term was multiplied by individual resting VO_2 , individual body mass, divided by 1000, multiplied by 5 (the assumption was made for an energy cost of 5 kcal/L of oxygen), and last multiplied by 60min (average daily duration of Pickleball match play).

Statistical analyses

All analyses were performed using SPSS Version 22.0 (Chicago, IL) and GraphPad Prism 6.0. (San Diego, CA). Measures of centrality and spread are presented as mean \pm SD. Primary outcome measures for

the acute cardiovascular and metabolic responses to Pickleball were relative exercise intensity (% HRR and % VO₂R), metabolic equivalents (METs), and energy expenditure (kcal/min and kcal/session). Primary outcome measures for the chronic cardiovascular and metabolic responses to Pickleball were the change in cardiometabolic risk factors, including VO₂max, weight, waist circumference, body composition, blood pressure, blood lipids, and blood glucose. Paired t-tests were used to compare the mean primary outcome measures between baseline and post-program. The probability of making a Type I error was set at $p < 0.05$ for all statistical analyses.

Results

Acute cardiovascular and metabolic responses to Pickleball

Cardiovascular and metabolic responses (mean \pm SD) to Pickleball for the fifteen participants (8 women and 7 men) who

completed the study are presented in Table 2. Overall heart rate for a Pickleball doubles match was 108.8 ± 16.7 beats/min, which corresponded to $50.9 \pm 11.2\%$ HRR and $52.5 \pm 11.3\%$ VO₂R. Absolute exercise intensity in METs was 4.1 ± 1.0 . Total energy expenditure for a Pickleball match equated to 353.5 ± 85.0 kcal/match. Figure 2 illustrates the exercise intensity in terms of HRR for a representative participant throughout a Pickleball match.

Chronic cardiovascular and metabolic responses to Pickleball

The chronic cardiovascular and metabolic responses to Pickleball are presented in Table 3 for all individuals who completed the intervention (N = 15). At 6wk, paired t-tests revealed favorable changes ($p < 0.05$) in HDL and LDL cholesterol, systolic and diastolic blood pressure, and VO₂max indicating a positive effect on cardiometabolic health.

Table 2. Acute cardiovascular and metabolic responses to Pickleball.

Parameter	Women (N=8)	Men (N=7)	Combined (N=15)
HR (beats/min)	107.2 ± 11.9	110.8 ± 22.6	108.8 ± 16.7
Range	79-133	79-158	79-158
%HRR	46.4 ± 7.3	56.2 ± 13.4	50.9 ± 11.2
Range	21-69	27-83	21-83
%VO ₂ R	53.3 ± 7.5	51.5 ± 15.7	52.5 ± 11.3
Range	12-80	12-86	12-86
METs	4.2 ± 0.9	4.1 ± 1.1	4.1 ± 1.0
Range	1.5-6.8	1.8-7.7	1.5-7.7
kcal/min	5.5 ± 0.9	6.4 ± 1.9	5.9 ± 1.4
Range	2.2-9.0	2.1-10.8	2.1-10.8
kcal/match	330.0 ± 54.7	381.6 ± 111.8	353.5 ± 85.0
Range	---	---	---

Values are mean \pm SD. (HR, heart rate; %HRR, percentage heart rate reserve; kcal, kilocalories; METs, metabolic equivalents; %VO₂R, percentage oxygen uptake reserve).

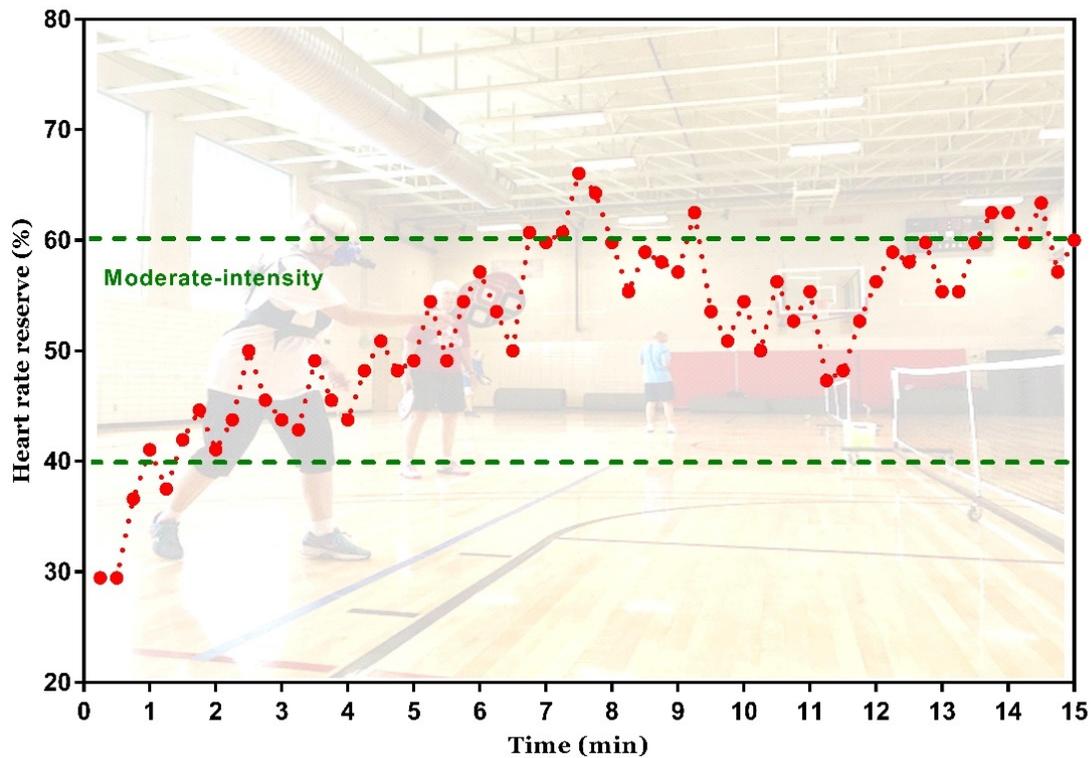


Figure 2. Exercise intensity in terms of heart rate reserve (HRR) for a representative participant throughout the duration of a Pickleball match. The dashed lines (-----) represent the moderate exercise intensity classification.

Table 3. Baseline (mean \pm SD) and mean change (95% CI) after the 6wk Pickleball intervention.

Variable	Baseline mean \pm SD	Change at 6wk mean (95% CI)	p-value difference to baseline
Weight (kg)	76.3 \pm 20.5	0.13 (-0.25 to 0.52)	0.465
Waist circumference (cm)	85.5 \pm 13.4	0.25 (-0.17 to 0.67)	0.214
Body fat (%)	30.3 \pm 6.6	-0.29 (-1.00 to 0.40)	0.373
Systolic blood pressure (mmHg)	135.1 \pm 11.4	-4.75 (-6.16 to -3.34)	<0.001*
Diastolic blood pressure (mmHg)	86.8 \pm 5.3	-2.50 (-4.37 to -0.63)	0.013*
TC (mg/dL)	182.3 \pm 44.3	2.42 (-4.89 to 9.72)	0.482
HDL (mg/dL)	62.0 \pm 17.8	3.08 (0.26 to 5.90)	0.035*
LDL (mg/dL)	104.0 \pm 31.8	-3.67 (-7.01 to -0.32)	0.034*
TRIG (mg/dL)	78.0 \pm 22.7	4.33 (-3.04 to 11.71)	0.223
GLU (mg/dL)	86.3 \pm 7.3	0.75 (-0.83 to 2.33)	0.319
VO ₂ max (mL/kg/min)	26.2 \pm 5.7	3.11 (2.44 to 3.78)	<0.001*

Note: confidence interval (CI), total cholesterol (TC), high density lipoprotein (HDL), low density lipoprotein (LDL), triglycerides (TRIG), blood glucose (GLU), maximal oxygen uptake (VO₂max). *denotes $p < 0.05$.

Discussion

Aging is frequently accompanied with increased levels of physical inactivity, which contributes to numerous unfavorable health consequences including decreased cardiorespiratory fitness levels. This is disconcerting as low cardiorespiratory fitness is strongly linked with an increased risk of cardiovascular disease (CVD), mortality from CVD, and all-cause mortality. Indeed, it has been proposed elsewhere that cardiorespiratory fitness should be employed as the ultimate marker for risk stratification and health outcomes⁶. Increased physical inactivity in older adults may be partially attributable to inaccessibility and lack of enjoyment, which makes familiar and popular land-based exercises such as walking, jogging, and cycling more difficult. The main finding of the present study is that regular participation in Pickleball elicits cardiovascular and metabolic responses that fulfill exercise intensity guidelines for improving and maintaining cardiorespiratory fitness^{5,7}. Mean exercise intensity was 50.9% of HRR, 52.5% of VO_2R , and 4.1 METs, respectively. Overall energy expenditure for Pickleball was ~350 kcal/match. Collectively, these findings support Pickleball as an ideal alternative form of physical activity for middle-aged and older adults.

Pickleball Intensity

Exercise intensity is arguably the most critical component of the exercise

prescription model. Failure to meet minimal threshold values may result in lack of a training effect, while too high of an intensity could lead to over-training and negatively impact adherence to an exercise program⁶. Results from the present study indicate Pickleball can be classified as “moderate” according to various organizations definition of physical activity intensity^{5,7}. For example, moderate exercise intensity in relative terms has been defined as 40-59% of HRR/ VO_2R ⁵. Participants in the present study exercised at workloads during Pickleball that elicited HRR (50.9%) and VO_2R (52.5%) values that fall within the moderate relative intensity category. However, it is also important to note the considerable between-subject variability in the HRR/ VO_2R responses to Pickleball (see ranges reported in Table 2). Although the mean exercise intensity response fell within the recommended “moderate” intensity range of 40-59% HRR/ VO_2R , it is also evident that for some participants the HRR/ VO_2R responses were above the “moderate” category and within the “vigorous” category of exercise intensity. Research is quite clear that for most individuals the benefits of low-to-moderate intensity exercise substantially outweighs any risks; however, for a small segment (i.e., **the high risk**) of the population, the risk of exercise-related events such as a heart attack or sudden death, is substantial when performing unaccustomed exercise bouts, in particular vigorous intensity exercise⁵. Consequently, caution may be

advised when recommending Pickleball for higher risk individuals (e.g., Type 2 diabetics or cardiac-diseased).

Metabolic Equivalent for Pickleball

In both the U.S. Surgeon General⁸ report on physical activity and elsewhere⁹, moderate-intensity physical activity in metabolic terms has been classified as 3 to 6 METS. In the present study, the MET response to Pickleball averaged 4.1 and ranged from 1.5 to 7.7. Thus, participants in the present investigation exercised at workloads during Pickleball that elicited metabolic responses within the accepted moderate-intensity range. This is an important finding given the fact that moderate-intensity exercise has been widely recommended for health benefits⁸. MET values described in the present study compare favorably to more traditional land-based aerobic values and non-traditional physical activity values. For instance, treadmill and over ground walking at 3.0 miles per hour is an equivalent moderate-intensity physical activity at 3.3 METS. Likewise, an 80kg individual cycling between 50 and 100 Watts will elicit a MET value ranging from 4.0 to 6.0 METS⁵. Moreover, Guderian and colleagues¹⁰ reported that playing Wii Fit video games is a feasible alternative to more traditional aerobic exercise modalities for middle-aged and older adults that elicits a 3.5 mean MET value response. More recently, we demonstrated¹¹ that Zumba Gold exercise produced a 4.3 mean MET response in middle-aged and older adults.

Pickleball Energy Expenditure

Research has demonstrated that there is a dose-response relationship between exercise and multiple health outcomes, including cardiorespiratory fitness, risk of coronary artery disease (CAD) and all-cause mortality, obesity, dyslipidemia, type 2 diabetes, and colon cancer¹². Based on these dose-response relationships, both the ACSM⁵ and U.S. Surgeon General⁸ have noted that the health benefits of a program are associated with the total weekly energy expenditure. Gross (total) energy expenditure includes both the resting metabolic rate and the energy expenditure attributable to the exercise itself (net caloric expenditure). For the improvement and maintenance of cardiorespiratory fitness, the ACSM has recommended a target energy expenditure of 150 to 400 kilocalories per day (kcal/day). From a practical perspective, results from the present study highlight that participation in an hour of Pickleball yields a mean energy expenditure of ~355 kcal that fulfills the ACSM recommendations for daily energy expenditure.

Chronic cardiovascular and metabolic adaptations to Pickleball

The results of the current study demonstrate that regular participation in Pickleball confers similar health benefits when compared to those achieved from traditional aerobic training. Indeed, playing Pickleball for 6wk resulted in significant improvements in the lipid profile, blood pressure, and cardiorespiratory fitness.

These positive adaptations to cardiometabolic health have novel clinical and public health relevance, as a large number of adults fall into clinically-defined categories of dyslipidemia, hypertension, and/or low cardiorespiratory and therefore demonstrate increased CVD risk^{5,13}.

Cardiorespiratory fitness has been coined the ultimate health outcome⁶, and for good reason; it has been shown that low cardiorespiratory fitness accounts for more deaths in both men and women than any other CVD risk factor¹⁴. Overall, VO_2 max was improved on average by ~ 1.0 METs following 6wk of Pickleball participation. These improvements likely have important long-term prevention implications as a recent study reported a 1 MET increase in VO_2 max was associated with an 18% reduction in deaths due to CVD¹⁵. Next to low cardiorespiratory fitness hypertension has been implicated in the second highest number of overall deaths amongst American adults according to one study¹⁴. Systolic and diastolic blood pressure were both significantly reduced in the presented study by ~ 5 mmHg and ~ 3 mmHg, respectively. Although these changes appear rather unassuming, it has been demonstrated that blood pressure decreases of as little as 2 mmHg are associated with a 6% decrease in stroke mortality and a 4% decrease in coronary artery disease¹⁶. Dyslipidemia refers to abnormalities in the blood lipid and lipoprotein profile of which elevations in total cholesterol, LDL cholesterol, and

triglycerides, along with low HDL cholesterol, are characteristic features. The positive modifications to HDL ($\uparrow \sim 3$ mg/dL) and LDL ($\downarrow 4\%$) observed in the present study have the potential to yield important overall cardiovascular health benefits. For instance, it has been estimated that for every 1 mg/dL increase in HDL cholesterol, the risk of a coronary heart disease event is reduced by 2 to 3%¹⁷. Moreover, it has been purported that for every 1% decrease in LDL cholesterol there is a corresponding 1% reduced risk for significant heart disease events¹⁸.

Methodological Considerations

Possible limitations to the present study merit discussion. The present study investigated the cardiovascular and metabolic responses to a representative sample of middle-aged and older adults participating in Pickleball. The cardiovascular and metabolic responses to Pickleball may vary across different populations. In particular, those older adult cohorts with balance impairments, mobility limitations, and/or more severe chronic disease may need further screening before exploring Pickleball as a viable form of physical activity. Another possible limitation is the relatively short resting period used for collecting resting HR and VO_2 . However, unpublished pilot testing data from our laboratory found no significant differences ($p > 0.05$) between resting HR and VO_2 values obtained following 5min and 30min of rest.

Conclusions

To our knowledge, this is the first study to investigate the cardiovascular and metabolic responses to Pickleball in middle-aged and older adults. Findings from the present study support Pickleball as a feasible alternative to traditional physical activity and exercise modalities for older adults that fulfills guidelines for improving and maintaining cardiorespiratory fitness. This is critical, as low cardiorespiratory fitness may contribute to premature mortality in this segment of the population¹⁹. Moreover, decreased cardiorespiratory fitness contributes to a reduction in physiological functional capacity and eventually can result in loss of independence²⁰. Overall, these findings are important for exercise professionals, physical therapists, and others who design exercise programs and/or promote physical activity for older adult populations.

Competing interests

This investigation was supported financially by the American Council on Exercise (ACE). The American Council on Exercise (ACE) was not involved in development of the study design, data collection and analysis, or preparation of the manuscript. There are no other potential conflicts of interest related to this article.

Address for Correspondence

Lance Dalleck, Ph.D., High Altitude Exercise Physiology Program, 600 N. Adams St., Western State Colorado University, Gunnison, CO, United States, 81231. Phone: 970-943-7132; Email: ldalleck@western.edu.

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