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Physical Activity Intensity of Singles and Doubles Pickleball in Older Adults

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The purpose of this study was to measure heart rate, activity intensity, and steps in recreational singles and doubles pickleball players. We collected data in 22 singles and 31 doubles players (62.1 ± 9.7 years of age) using Garmin Fenix 5 watches (Garmin International, Inc.) and ActiGraph GT3X+ (ActiGraph LLC) accelerometers. Mean heart rates during singles and doubles were 111.6 ± 13.5 and 111.5 ± 16.2 beats/min (70.3% and 71.2% of predicted maximum heart rate), respectively. Over 70% of singles and doubles playing time was categorized in moderate to vigorous heart rate zones whereas 80.5% of singles time and 50.4% of doubles time were moderate based on Freedson accelerometer cut-points. Steps per hour were higher in singles versus doubles (3,322 ± 493 vs. 2,791 ± 359), $t(51) = 4.540$, $p < .001$. Singles and doubles pickleball are moderate- to vigorous-intensity activities that can contribute substantially toward older adults meeting physical activity guidelines.

Keywords: accelerometer, cadence, heart rate

Pickleball, a game that incorporates many elements of tennis, badminton, ping pong, and racquetball, is said to be one of the fastest growing sports in the United States and Canada (Pickleball Canada, 2022; USA Pickleball, 2022a). Recent statistics suggest there are 4.8 million players in the United States, representing a 39% increase over the past 2 years (USA Pickleball, 2022a), and one million Canadians play pickleball, a near tripling of numbers in 2 years (Pickleball Canada, 2022). The game attracts many older participants; 54% of "core" players (individuals who play eight or more times per year) in the United States (USA Pickleball, 2022a) and 84% of active members registered with Pickleball Canada are 55 years of age or older (P. Milovanovic, personal communication, April 28, 2022).

Singles and doubles pickleball can be played indoors or outdoors with a perforated hard plastic ball and a solid paddle on a badminton-sized court (6.10 × 13.41 m; USA Pickleball, 2022a). The sport is relatively easy for beginners to learn and can develop into a fast-paced, competitive game for intermediate and elite players. Pickleball represents a "serious leisure activity" for many older adults (Heo et al., 2018; Ryu et al., 2022). Serious leisure activities are associated with meaningful engagement and high levels of commitment, often taking priority over other things (Stebbins, 2007). As a serious leisure activity, playing pickleball has been shown to be associated with subjective well-being which is linked to greater life satisfaction, higher quality of life, and positive perceptions of aging (Heo et al., 2018). Research investigating psychological connection to pickleball suggests that older adults play to satisfy needs for ongoing development of personal mastery (Buzzelli & Draper, 2020; Casper & Jeon, 2019), as well as for fitness, and socialization (Casper & Jeon, 2019).

Despite the huge rise in popularity, little exists in published literature regarding the physiological demands of the sport. One study measured cardiovascular and metabolic data in 15 participants (65.2 ± 8.0 years of age) while they played doubles pickleball for 1 hr, and during a maximal graded exercise test on a treadmill (Smith et al., 2018). Mean heart rate during pickleball was 108.8 ± 16.7 beats/min, corresponding to 50.9 ± 11.2% heart rate reserve, which is categorized as moderate intensity (Riebe et al., 2018, p. 146). Mean oxygen uptake levels also reached moderate intensity levels of 52.5 ± 11.3% oxygen uptake reserve, and absolute exercise intensity was equivalent to 4.1 ± 1.0 metabolic equivalents. In another study, intensity of physical activity associated with pickleball was measured with an accelerometer in 25 doubles players (59.0 ± 15.8 years of age) during two to five games (Boudreaux & Schmidt, 2019). Categorization of activity intensity using counts/min (cpm) with Sasaki cut-points (Sasaki et al., 2011) resulted in the majority of time spent playing (63.5 ± 14.3%) registering in moderate- to vigorous-intensity zones. An additional study of 12 younger players (48.5 ± 13.1 years of age) reported peak heart rates of 140.5 ± 18.4 beats/min and mean heart rates of 117.3 ± 15.5 beats/min during 30 min of doubles play (Smith et al., 2016). Data collected in novice- to intermediate-level players found mean and peak cadence values of 80.3 ± 9.2 and 194.4 ±17.9 steps/min, respectively (Denning et al., 2016). Monitoring time during all previous investigations was relatively short, ranging from 30 min to approximately 75 min, and all studies evaluated doubles play.

Given the high levels of recent uptake of pickleball (Pickleball Canada, 2022; USA Pickleball, 2022a) and the significant role pickleball plays in contributing to well-being, quality of life, and positive aging for many older adults (Heo et al., 2018), it is important that researchers, clinicians, and older adults themselves understand the activity demands of the sport. To date, published findings have been limited to relatively small sample sizes and doubles participation. The purpose of this study was to measure heart rate, activity intensity, and steps in adult recreational pickleball players during singles and doubles play. We were interested in determining relative physical activity intensities during play using both heart rate and accelerometer cut-points, and differences between singles and doubles, to better understand how playing

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pickleball may contribute to meeting recommended physical activity levels in older adults.

Methods

Study Design and Participants

Following institutional ethical approval, informed consent was obtained from 32 recreational doubles pickleball players and 22 singles players who volunteered after hearing about the study through an email advertisement circulated through local groups of players. The researchers attended outdoor pickleball sessions organized by the participants in July and August 2021 to collect doubles data. Singles data were collected indoors from September to November 2021. Four individuals participated in both the doubles and singles data collection sessions. All participants were adults who were familiar with the sport. Participants completed a demographic questionnaire and were asked to rate their skill level according to USA Pickleball's definitions of player skill ratings (USA Pickleball, 2022b). All participants were familiar with this skill rating system which ranges from 1.0 to 5.5+ (e.g., skill rating 1.0 describes a player new to pickleball with no other sports background and minimal understanding of the rules of pickleball and 5.5 describes a top caliber player with multiple high-level tournament wins). Participants were instructed to warm up by walking or jogging around the courts for 3 min at an intensity they felt was "moderate." Participants then continued their warm-up on the court hitting various pickleball shots for 2–5 min before beginning game play. Game play continued for a minimum of 1 hr, with short breaks occurring if participants had to rotate off a court and wait for the next available court to begin their next game. They were asked to sit or stand relatively still between pickleball games (e.g., on the sidelines, if they had to wait for the next court) so that this inactive time could be recognized in the accelerometer data.

Measures

Following accepted practices, participants wore an ActiGraph GT3X+ accelerometer (ActiGraph LLC) on an elastic strap over the right iliac crest (Migueles et al., 2017) and a Garmin Fenix 5 smart watch (Garmin International, Inc.) on their nondominant wrist for the warm-up and during pickleball play. The GT3X+ monitors were initialized using ActiLife6 software (version 6.13.3; ActiGraph LLC) to collect data at 100 Hz. ActiGraph GT3X+ monitors have been shown to be valid for measuring steps (Jones et al., 2018; Lee et al., 2015) and moderate to vigorous physical activity (O'Brien et al., 2018) at walking and jogging speeds. Heart rate was collected every second using the "Activity" function on the Fenix 5 watches. Outdoor temperature (including humidex) was recorded for doubles play from historical weather data (https://climate.weather.gc.ca/historical_data/search_historic_data_e.html).

Few studies have reported on the accuracy of using Garmin Fenix 5 watches for measuring heart rate in active individuals (Düking et al., 2020; Navalta et al., 2020). We measured heart rate in two young people (aged 25 and 32) concurrently using a Fenix 5 watch on the nondominant wrist and a Welch Allyn Propaq CS 244 Patient Monitor ECG machine (Welch Allyn Inc.). The individuals were monitored at rest and while they walked and ran on a treadmill at speeds ranging from 4.8 to 12.9 km/hr. Heart rates were recorded from the watch and the Propaq ECG machine simultaneously every 15 s for a total of 149 data points. Propaq ECG heart rate values ranged from 60 to 181 beats/min. Mean absolute percentage error between the Propaq and Fenix 5 measured heart rates was 3.3 beats/min. Eighty-one percent of all heart rates recorded with the Fenix 5 watch differed by ≤5 beats/min compared with Propaq values.

Data Analysis

GT3X+ accelerometers were downloaded with ActiLife6 to obtain 1-s epoch files which were then reintegrated to obtain 10s and 60-s CSV files. A custom R program (https://www.r-project.org/) was used to detect bouts of stepping activity during pickleball play using the 10-s epoch files. The number of steps per 10 s needed to represent the start of a bout was set to three. The minimum number of epochs required to be considered a bout was 12 (120 s), and the number of epochs allowed below the step threshold was six (consecutive or nonconsecutive epochs below threshold). If measured steps were below threshold in >6 epochs, that marked the end of the activity bout. These settings were pilot tested and compared with observed active and inactive time during five pickleball sessions prior to adopting them for data analysis. Activity bout start, and end times were noted. Time between bouts was considered "nonplay" time, and these data were removed from the 60-s CSV files. The warm-up time was easily identified in the 60-s file as the consistent high cadence data (typically 90–140 steps/min) apparent for 3 min shortly after the start time of the recording. The first bout of activity detected after the warm-up was designated as the beginning of pickleball play. The end time of pickleball play was the end of the last bout of activity that occurred before the Fenix 5 heart rate data collection stopped.

We extracted the following variables from the steps per minute data collected by the GT3X+ device during play: peak cadence (single largest value), mean cadence, total steps, and total minutes of play. We then filtered the GT3X+ axis 1 (vertical) cpm data to determine minutes of light-intensity activity (100–1,951 cpm), minutes of moderate-intensity activity (1,952–5,724 cpm), and minutes of vigorous-intensity activity (>5,724 cpm) according to the accepted Freedson cut-points (Freedson et al., 1998).

The FIT files were downloaded from the Fenix 5 watches and imported into FitFileRepairTool (version 8.13.20; Krallmann, 2021) for conversion to 1-s CSV files. Inactive minutes determined from the GT3X+ data analysis were deleted; heart rate data were retained for the 3-min warm-up and all of the pickleball play time. Mean heart rate during the last minutes of the 3-min warm-up and mean heart rate during pickleball play were calculated from the 1-s heart rate data. The formula "220–age" (Fox et al., 1971) was used to determine predicted maximum heart rate, and mean heart rate was expressed as a percentage of maximum predicted heart rate for each participant. This formula is simple to apply and is commonly used to predict maximum heart rate (Riebe et al., 2018, p. 149). Heart rate values were then averaged per minute, and minutes of play were categorized as light intensity (<64% maximum predicted heart rate), moderate intensity (64%–76% maximum predicted heart rate), and vigorous intensity (>76% maximum predicted heart rate; Riebe et al., 2018, p. 146).

Statistical Analysis

Descriptive statistical analysis was conducted using SigmaPlot (version 11.0, Systat Software Inc.). Data were checked for normality using the Shapiro–Wilk test. Two-tailed independent *t* tests were conducted to assess for differences between singles and doubles play.

Results

Characteristics of the 22 singles and 31 doubles pickleball participants are shown in Table 1. Data from one doubles participant were not included in analyses because the humidex value was >30 °C on the day of play. In addition, we were unable to retrieve heart rate data from Fenix 5 watches for two doubles participants. The gender ratio (female/male) for the singles group was 9:13 and for the doubles group was 16:15. Self-reported player skill ratings ranged from 2.5 to 4.5 for the singles players and from 3.0 to 4.5 for the doubles players (USA Pickleball, 2022b). The range of years of experience with the sport was similar between singles and doubles players (0.3–8.0 years and 1.0–8.0 years, respectively). When comparing the number of hours of pickleball played per week, the majority of participants from the singles group played 3–7 hr whereas the majority of the doubles participants played 5–11 hr.

Heart rates recorded during the warm-up (continuous walk or jog) ranged from 71 to 149 beats/min, with a mean of 107.2 ± 17.0 beats/min. Activity intensity of the singles and doubles pickleball players based on the heart rate and accelerometer results is shown in Table 2. Doubles data were collected over an average of 35.3 min longer compared with singles, $t(51) = -6.391$, $p < .001$. Absolute mean heart rates achieved were identical in singles and doubles players (112 beats/min), and absolute maximum heart rates were also very similar (144 vs. 141 beats/min, respectively). Both singles and doubles players spent just over 70% of play time in moderate and vigorous heart rate zones, and there were no statistical differences between the groups in time spent in light, moderate, and vigorous heart rate zones. Based on the accelerometer cpm, the majority of singles pickleball play (80.5%) was moderate intensity, a small percentage (19%) was light intensity, and there was virtually no vigorous intensity time. The doubles participants spent almost an equal amount of time at light (49.6%) and moderate intensities (50.4%) and, similar to the singles players, almost no time at a vigorous intensity. Mean cadence and steps per hour were higher in singles compared with doubles, 11.6 steps/min, $t(51) = 6.902$, $p < .001$ and 532 steps/hr, $t(51) = 4.540$, $p < .001$, greater for the singles players, respectively.

Mean outside temperatures were determined for the doubles participants from historical weather data. The mean temperature including humidex was 26.9 ± 2.5 °C.

Table 1 Characteristics of Participants

Characteristic	Singles players Mean ± *SD* or frequency (*n* = 22)	Doubles players Mean ± *SD* or frequency (*n* = 31)
Age (years)	61.0 ± 11.8	62.8 ± 8.1
Skill level	3.5 ± 0.5	3.6 ± 0.3
Years playing pickleball	4.5 ± 2.4	4.4 ± 1.7
Play/week (hr)		
0–3	3	0
3–5	7	4
5–7	5	7
7–9	1	7
9–11	2	7
>11	4	6

Note. Skill rating as per USA Pickleball's definitions of player skill ratings (USA Pickleball, 2022b).

Discussion

The purpose of this study was to categorize physical activity levels achieved during singles and doubles pickleball using both heart rate and accelerometer cpm variables. We collected data in 53 pickleball players (22 singles and 31 doubles) over 71 min of playing time for singles and 106 min for doubles. Inactive time between games on court (22.3% of total monitoring time for singles and 21.3% for doubles) was filtered out of the data. Mean heart rates achieved during singles and doubles play met the criteria for moderate intensity physical activity (64%–76% maximum predicted heart rate; Riebe et al., 2018, p. 146), and the percent of time spent in moderate and vigorous heart rate zones did not differ between singles and doubles (72.7% and 71.6%, respectively). The majority of active play time was also categorized as moderate intensity using Freedson accelerometer cpm cut-points (singles: 80.5% and doubles: 50.4%), although a substantial portion of doubles time was also spent in light-intensity activity (49.6%). Mean steps per hour of play were higher in singles compared with doubles.

The mean and peak heart rate values observed in doubles participants in our study were comparable to those previously reported in smaller samples of similarly aged pickleball players (Smith et al., 2018). Mean heart rate was 111.5 beats/min, and peak heart rate was 141.0 beats/min in our doubles participants (mean age 62.8 years), whereas Smith et al. (2018) reported values of 108.8 bpm and 158.0 bpm in pickleball players with a mean age of 65.2 years. Data reported in younger pickleball players (mean age 48.5 years) are also consistent with mean heart rates of 117.3 beats/min and peak heart rates of 140.5 beats/min reported (Smith et al., 2016). Mean heart rates for participants in our study reached 70%–71% of predicted maximum heart rate. This is similar to what has been previously reported for middle-aged recreational and advanced-level tennis players during 1 hr of singles match play, where mean heart rates were equal to 80%–81% of the maximum heart rates measured during a maximal treadmill test (Fernandez-Fernandez et al., 2009). Likewise, mean heart rates were reported to reach 68.8% of predicted maximum during singles tennis practice sessions and 71.6% of predicted maximum during singles game play in a small sample of college-aged players (Barfield et al., 2009).

One previous study also used ActiGraph GT3X+ accelerometers to categorize physical activity intensity using cpm during doubles pickleball (Boudreaux & Schmidt, 2019). They reported that 47.1% of game play registered at moderate intensity and 16.4% was vigorous intensity using Sasaki cut-points. In comparison, we found that 50.4% of doubles was moderate intensity and 0.03% was vigorous using Freedson cut-points. Sasaki cut-points (Sasaki et al., 2011) analyze vector magnitude activity counts (acceleration measured in three planes) with 2,690–6,155 cpm representing the moderate intensity range, whereas Freedson vertical acceleration cut-points (Freedson et al., 1998) assign 1,952–5,724 cpm as moderate-intensity activity. We chose to use Freedson cut-points for our analysis because they are commonly used to quantify physical activity in older adults (Gorman et al., 2014). Given the variations in analytic techniques that Boudreaux and Schmidt (2019) employed, their findings are not substantially different from ours. Both studies found that at least 50% of doubles time can be categorized as moderate or higher intensity based on accelerometer cut-points in recreational older adult samples.

Step data collected with the accelerometers demonstrated that mean cadence was higher during singles play compared with doubles (57.4 vs. 45.8 steps/min, respectively) and steps per

Table 2 Activity Intensity During Play (Heart Rate and Accelerometer Results)

Characteristic	Singles players Mean ± *SD* *n* = 22	Doubles players Mean ± *SD* *n* = 31[a]
Minutes of play	70.8 ± 18.5*	106.1 ± 20.7
Mean HR (bpm)	111.6 ± 13.5	111.5 ± 16.2
Mean HR (% maximum predicted)	70.3 ± 7.2	71.2 ± 10.1
Maximum HR (bpm)	144.2 ± 16.7	141.0 ± 17.4
Percent play in light HR intensity zone	27.5 ± 25.2	28.4 ± 30.2
Percent play in moderate HR intensity zone	45.2 ± 24.8	38.1 ± 22.7
Percent play in vigorous HR intensity zone	27.5 ± 29.5	33.5 ± 31.3
Percent play in light intensity (0–1,951 cpm)	19.0 ± 13.5*	49.6 ± 22.5
Percent play in moderate intensity (1,952–5,724 cpm)	80.5 ± 13.3*	50.4 ± 22.5
Percent play in vigorous intensity (>5,724 cpm)	0.01 ± 0.02	0.03 ± 0.15
Mean cadence (steps/min)	57.4 ± 7.0*	45.8 ± 5.2
Peak cadence (steps/min)	83.7 ± 8.4	80.6 ± 13.8
Steps per hour	3,322 ± 493*	2,790 ± 359
Percent total time in active play	77.7 ± 13.7	78.7 ± 8.4

Note. HR = heart rate; bpm = beats per minute; cpm = counts per minute.
[a]Doubles HR data ($n = 29$).
*$p < .001$ (t test).

hour were also greater during singles (3,322 vs. 2,791, respectively). There were no differences in peak cadence between singles and doubles (83.7 vs. 80.6, respectively). One other study in novice to intermediate-level pickleball players (44 ± 14 years of age) also reported cadence results measured with a Hexoskin vest (Denning et al., 2016). Interestingly, our peak cadence values are very similar to the mean cadence value of 80.3 steps/min reported by Denning et al. (2016) and our peak cadence values (83.7 and 80.6 steps/min) are much lower than those reportedly measured with the Hexoskin vest (194.4 steps/min). These discrepancies may relate to the epochs used for analysis. We calculated cadence based on full minutes of data. However, if Hexoskin software uses a shorter window of data capture and then extrapolates to full minutes, the cadence values may be inflated (notably, a cadence of 194.4 steps/min is greater than that typically achieved during running; Futrell et al., 2021).

Our findings demonstrated discrepancies between the percent of play time in moderate- and vigorous-intensity heart rate zones compared with play time in moderate and vigorous intensity categories defined by accelerometer cut-point values. For example, in singles players, 45.2% and 27.5% of play time was in the moderate and vigorous intensity heart rate zones, respectively, whereas 80.5% and 0.01% of play time was in moderate and vigorous intensity categories according to Freedson accelerometer cut-points (Table 2). This discrepancy is likely reflective of the fact that older adults have lower resting metabolic rates compared with younger adults and, therefore, accelerometer cut-point thresholds established in younger adults samples (like those by Freedson et al., 1998) underestimate older adults' time spent in higher intensity activities (Barnett et al., 2016). In our sample, it is likely that time in vigorous-intensity activity (>5,724 cpm) in singles, and time in moderate-intensity activity (1,952–5,724 cpm) in doubles were underestimated by using Freedson cut-points for analysis. This is a common issue when using accelerometers to quantify physical activity in older adults (Gorman et al., 2014).

Smith et al. (2016) also measured level of exertion and level of enjoyment in 12 novice- to intermediate-level pickleball players. Ratings of perceived exertion were greater for 30 min of doubles pickleball compared with 30 min of walking at a self-selected pace (Ratings of perceived exertion 11.0 vs. 8.9, respectively). Level of enjoyment was also greater in pickleball compared with walking. Walking is reported to be the most common physical activity that older adults regularly engage in (Reitlo et al., 2018; Valenti et al., 2016). However, pickleball may be more enjoyable and result in greater levels of exertion compared with walking. Our data suggest that both singles and doubles pickleball meet heart rate and accelerometer cut-point thresholds to be categorized as moderate- to vigorous-intensity physical activity. As such, time spent playing pickleball may contribute substantially to meeting recommended physical activity levels for older adults as set out by the Canadian 24-Hour Movement Guidelines (Canadian Society for Exercise Physiology, 2021) and the Physical Activity Guidelines for Americans (Piercy et al., 2018). In our participants, 78% of on-court time was active time, and 72% of active time resulted in heart rates in the moderate and vigorous heart rate zones. This suggests that engaging in approximately 4.5 hr of pickleball per week would allow older adults to meet physical activity guidelines of 150 min of moderate- tovigorous-intensity activity per week.

Our study has some limitations. We did not ask participants whether they were taking any medication that affected their heart rate, so it is possible that some heart rate data may have been blunted by medication such as beta-blockers that are relatively commonly prescribed in older adults. However, it is likely that this would have only affected a small number of participants, and our data demonstrated that the majority of play time was at a moderate- to vigorous-intensity (not a lower intensity) based on the heart rates measured. Participants engaged in doubles played outdoors during the summer months and the temperature (including humidex) was 26.9 °C . While we did not measure indoor temperatures experienced by the singles players, they were likely lower than those encountered outdoors. This difference may have resulted in

relatively greater heart rates in the doubles players compared with what they would have experienced in cooler conditions. However, it should be noted that pickleball is routinely played outdoors under similar (warm) conditions; therefore, the doubles heart rate data are likely very representative of those experienced during typical play.

We used Freedson cut-points for our accelerometer analyses; however, use of different accelerometer cut-points would result in different categorizations of time spent in light, moderate, and vigorous (Cleland et al., 2020; Gorman et al., 2014). Participants in our study were primarily intermediate-level players. Our results are not generalizable to beginner or very advanced players. Related to this, while the majority of our participants played at a similar skill level, we made no attempt to match players with those of similar abilities and this may have resulted in some degree of mismatch in the physical activity intensities experienced by players in some matches. This likely would have been most apparent in singles play. In addition, we did not match the singles and doubles play for duration (i.e., mean play time was 106 min for doubles vs. 71 min for singles). This may also have affected activity intensities; however, for recreational players, it is typical that people playing doubles engage for longer periods of time compared with those playing singles.

In conclusion, we have demonstrated that singles and doubles pickleball in older adults are primarily moderate- to vigorous-intensity activities, whether intensity is gauged based on heart rates or accelerometer counts per minute. Many social and psychological benefits have also been associated with the sport (Buzzelli & Draper, 2020; Casper & Jeon, 2019; Heo et al., 2018; Ryu et al., 2022). Future studies should measure activity intensity in players of different skill levels (e.g., beginners) and track changes in activity intensity with progression in the sport. In addition, measuring changes in physiological parameters such as blood pressure and bone density in response to regular pickleball training will be important to understand the longitudinal physical health benefits.

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