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The Effects of a Novel Sport-Based Intervention on Lower Body Muscle Function in Older Adults

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THE EFFECTS OF A NOVEL SPORT-BASED INTERVENTION ON LOWER BODY MUSCLE FUNCTION IN OLDER ADULTS

by

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ABSTRACT

Objective: This study aimed to examine the effects of a novel, small-court racquet sport, Pickleball, on lower body muscle power and functional performance of older adults, aged 60-75.

Background: Physical inactivity in the older adult population is associated with increased risks of falls, chronic illness, and decreased quality of life. Sports participation may have multiple benefits for improving these risks and have the added benefit of increased adherence among older adults. Pickleball, a popular new sport, is a small-court racquet sport that is moderate intensity, widely accessible, cost effective, and enjoyed by many older adults across the nation.

Methods: Five participants performed three isokinetic maximum voluntary contractions at $240°\cdot s^{-1}$ for the knee extensor's muscle group and three vertical jumps for measuring knee extensor power and lower body function, respectively, at baseline and after participating in 6 weeks of Pickleball play. Pickleball sessions were 1hour and occurred twice per week. Variables included mean knee extensor power and countermovement vertical jump height.

Results: The intervention resulted in moderate gains in knee extensor power (18.7% increases) and small gains in vertical jump height (7.5% increases). The effect sizes were 0.63 and 0.17 for the knee extensor power and jump height variables, respectively.

Conclusions: These findings offer some support showing that 6 weeks of Pickleball participation may elicit some modest gains, in a relatively short duration, for lower body function which could help older adults meet physical activity recommendations and help reduce the burdens of dysfunction on a long-term basis with a sport-based model that may offer advantages of sustainable physical activity. However, more work is needed to corroborate these findings with larger sample sizes and longer duration interventions.

INTRODUCTION

Physical inactivity has been linked to a multitude of diseases and disorders such as heart disease, stroke, type II diabetes, depression, and some cancers, according to the Centers for Disease Control and Prevention (CDC, 2014). According to the CDC, as of 2016, only about 21% of all U.S. adults met the *2008 Physical Activity Guidelines for Americans*. The CDC guidelines specifically recommend that adults perform at least 2.5 hours per week of moderate-intensity aerobic activity or 75 minutes per week of vigorous-intensity aerobic activity. Furthermore, the CDC also recommends that all adults perform muscle strengthening exercises two or more days each week. These guidelines are founded upon well documented evidence showing that regular physical activity at certain threshold levels provides a comprehensive set of health benefits for adults of all ages (Moore, et al., 2012; Wen, et al., 2011).

The benefits of physical activity extend beyond the realm of chronic disease prevention into other domains of physical and mental health, performance, and daily activities of living. For example, physical activity in its various forms has been shown to be associated with a higher quality of life (Bize, Johnson, & Plotnikoff, 2007; Martin et al. 2009), enhanced functional ability and/or reduced prevalence of disability (Capodaglio, Edda, Facioli, & Saibene, 2007; Leveille, Guralnik, Ferrucci, & Langlois, 1999), and independent living (Marques, et al., 2014) in middle-aged and older adults. Unfortunately, the most recent statistical report provided by the CDC in 2016 showed that, over a several year period, only 11% of adults over the age of 65 met the 2008 federal physical activity guidelines (achieving only half the physical activity guideline compliance as the general adult population). This is both alarming and unfortuante given that the collective benefits of structured physical activity (i.e., exercise) for chronic disease management and overall physical function are likely heightened for older populations because the risks for incurring such diseases or dysfunctions are known to increase exponentially with age.

Older adults give several reasons for not engaging in regular exercise. The primary reasons given are, 1) poor health (Schutzer & Graves, 2004), 2) time commitments (Chao, Foy, & Farmer, 2000), and 3) lack of knowledge on the appropriate exercise "dose", or in other words, fundamental exercise prescription principles (Chao, Foy, & Farmer, 2000; Schutzer & Graves, 2004). Moreover, the findings of McAuley et al. (2003) demonstrated that social support is one of the most important factors contributing to exercise adherence in older adults, and further suggested that increased levels of social support within an exercise context plays an important role in how enjoyable the exercise experience is perceived by this population (McAuley, Jerome, Elavsky, Marquez, & Ramsey, 2003). Although many older adults seek help for their declining health and pain from their doctors, who often advise their patients to regularly engage in exercise, there is usually no prescription or further guidance provided regarding optimal exercise programming (e.g., mode, frequency, intensity, or duration) to help improve their health and function. Exercise is traditionally performed alone and the routine is frequently self-selected which increases the time commitment and difficulty level for learning a routine – factors that may ultimately decrease adherence (Chao, Foy, & Farmer, 2000). Collectively, these aforementioned issues form barriers for exercise participation and long-term maintenance in older adult populations. It has been estimated that exercise dropout rates are ~50% within the first 6 months (Chao et al., 2000). It stands to reason that older adults would benefit from an exercise model which is capable of overcoming many of these stated barriers to exercise participation (e.g., increased social support, enhanced enjoyment, low programming complexity, etc).

Participating in team sports as a form of exercise is an intervention ideally suited for overcoming several of these barriers because of the potential for a strong social element, the multifactorial nature of the physiological stimulus they can provide, and their high intrinsic enjoyment (Kolt, Driver, & Giles, 2004). Kolt et al. (2004) provide support for the use of sport as an exercise model as they report that 40% of respondents from a sample of 812 men and women indicated that two reasons they engage in sport play is that they like the social aspect and that it gets them out of the house.

Recently, the benefits of playing sports has received considerable research attention as an effective means to improve a number of health and performance parameters and to reduce chronic disease and all-cause mortality risk. For example, Sundstrup et al. (2016) investigated the effects of recreational football training on functional capacity and lower limb muscle function in older adults (mean age = 68 years). Their findings showed that 1 year of football training significantly improved (24-50%) functionality (sit-to-stand, jump height and stair climbing ability) and also increased maximal strength of the hamstrings muscle group by 18% (Sundstrup, et al., 2016). Moreover, the findings of Krustrup et al. (2010b) revealed that recreational football training in premenopausal women (mean age = 40 years) induced significant improvements in bone mineral density (2.3%), muscle strength (16-27%), balance, and cardiac adaptations. In regards to mortality risk, a recent study by Oja, et al. (2017) examined the associations of six different sport or exercise types with all-cause and cardiovascular disease mortality in 80,306 men and women, between 30-98 years of age. Their findings showed that regular participation in racquet sports (badminton, tennis, squash) provided the greatest reductions in all-cause (hazard ratio; HR = 0.53) and cardiovascular disease (HR = 0.44) mortality risk compared to all the other exercise and sport types investigated (including cycling, swimming, aerobics, football and running; HR range of 0.72 – 0.87 for all-cause and 0.59 – 0.93 for cardiovascular disease risk, respectively).

Taken together, a team-based racquet sport may be a well-suited exercise model for overcoming exercise adherence barriers while at the same time eliciting improvements in key health and fitness parameters. Traditional racquet sports (i.e., racquetball, tennis), however, are characterized by high velocity, high impact movements, as well as a high degree of difficulty in developing the sport-specific skills, which renders these particular sports unfavorable as a safe and feasible exercise mode for older adults, especially those that are less active or naïve to racquet sport participation.

A smaller court racquet sport called Pickleball has recently become popular among older adults because it may overcome several of these aforementioned barriers. Pickleball may be a fitting racquet sport for this population due to an ideal balance between physical challenge and lowered injury risk while also featuring low entry skill level requirements. Briefly, it is a moderate-intensity game, similar to tennis or badminton that is played either indoors or outdoors and comprises two teams of two players. Importantly, it is well tolerated and enjoyed by persons of all ages, particularly those of older generations. Heo et al. (2017) have reported that Pickleball is an ideal leisure-time physical activity, and that it can have positive benefits for older adults as they continue to age. Moreover, Pickleball is highly accessible due to the low cost of equipment and readily available venues. This combination of accessibility, potential for broad health benefits, and increased likelihood for adherence due to its positive social structure and enjoyment levels, suggest that Pickleball may offer an effective and low cost way to benefit the health and functional capacity of older adults on long-term basis. There are no studies that have investigated the effects of regular Pickleball participation on health or function in older adults. However, Laurson and colleagues (2008) examined the heart rate response to a session of Pickleball in high school students and reported that their heart rates were above 50% of their age-predicted maximum heart rate for an average of 68±30.5% of the session. This indicates that the intensity level of Pickleball is within the recommended target heart rate zone for this population.

One important physiological/performance domain which Pickleball may be beneficial for is the area of muscle function, which includes the key parameters of strength and power. Muscle function is especially important in older adults because of their vulnerability to the age-associated loss of these capacities, which are strongly associated with overall health (Payne, Gledhill, Katamarzyk, Jamnik, & Ferguson, 2000; Westcott, 2012; Wolff, 2006), functional impairment risk (Foldvari, et al., 2000; Reid & Fielding, 2012) and mortality (Li, et al., 2017; Newman, et al., 2006). Skeletal muscle power is a muscle function attribute that is particularly vulnerable to age-related effects because it declines earlier and more rapidly in older adults compared to muscle mass and strength loss. This loss of power increases the risk for falls which increases health care costs and can lead to early mortality (Buehring, Krueger, & Binkley, 2010; Reid & Fielding, 2012). Lower body power-based performance, such as the vertical jump, has been shown to correlate well with functional assessments such as the Get-Up-and-Go test and the chair-raising test (Runge, Rittweger, Russo, Schiessl, & Felsenberg, 2004) that are used to evaluate the risk of falling and muscular decline in older adults (Buehring, Krueger, & Binkley, 2010; Runge, Rittweger, Russo, Schiessl, & Felsenberg, 2004). Thus, research is warranted that examines the effectiveness of Pickleball as a sport-based exercise mode to improve lower body muscle function characteristics in older adults Therefore, the purpose of this preliminary study is to determine the effects of 6-weeks of regular Pickleball participation on lower body muscle strength and power in a population of older adults (+60 years) who are naïve to racquet sport play.

METHODS

Participants

Six participants were recruited from the local community and enrolled in the study; however, one participant did not complete all 6-weeks of the intervention and thus was removed from the data analyses. Demographics of the five participants (four women and one man) that completed the study is as follows: mean ± SD, age = 65.8 ± 3.6 years, weight = 84.2 ± 16.8 kg, height = 168.5 ± 10.8 cm. Inclusion criteria required that participants were between the ages of 60 and 75 years, had not played racquet sports within the last 5 years and were classified as sedentary or recreationally active but not involved in regular vigorous activity (they performed less than 2 hours of vigorous exercise per week). This study was approved by the University's Institutional Review Board, and an informed consent document was read and signed by each participant prior to beginning the study.

Experimental Procedures

The present study used a prospective cohort design to examine the effects of 6 weeks of playing Pickleball on the outcome measures. Participants reported to the lab for testing before and after the intervention. The pretest included a basic health screening followed by measurements of height, weight, waist circumference, and a blood pressure assessment. Participants then did the muscle function assessments, which included vertical jumps and dynamometer-based maximum voluntary contractions (MVCs).

Dynamometer Assessment

Participants were seated on a Biodex dynamometer (Biodex System 3, Biodex Medical Systems Inc., Shirley, NY, USA) with restraining straps placed over their hips and thigh, and their lower leg was fixed to a padded lever arm at 5 cm above the lateral malleolus. Following a submaximal 10 repetition warm-up, participants performed isokinetic MVCs using their dominant leg. Three isokinetic MVCs were performed at $240°\cdot s^{-1}$ for the knee extensor's muscle group.

Vertical Jump

The vertical jump test was used as a functional indicator of lower body power output. Participants performed three countermovement jumps (CMJ) on a jump mat (Just Jump Technologies, Huntsville, AL, USA) with their shoes on, and with their hands placed on their hips to remove any influence of arm-swing on the jump performance. Participants had a 60-second rest provided between each jump.

Data Analyses

The raw torque signal from the Biodex was sampled at 2 kHZ with a Biopac data acquisition system (MP150WSW, Biopac Systems Inc., Santa Barbara, CA). The torque signals were stored on a PC and processed offline with custom written software (LabVIEW 2016, National Instruments, Austin, TX). The torque and velocity signals were filtered using a fourth order, zero phase shift Butterworth filter with a low-pass cutoff of 50 Hz. Isokinetic MVCs were corrected for the effect of gravity of the lower limb per the procedures of Aagaard et al. (1995). A power signal was derived as the product of the torque and velocity signals and mean power was calculated as the mean of the power values between knee joint angles of 60° and 30° (0° = horizontal).

Sport Intervention

The participants played Pickleball on an indoor pickleball court twice per week, for a total of 6 weeks. Each session lasted 1-hour and games were played with two teams of two players. The first week was used to teach and familiarize the participants the rules of the game, as well as for practicing the basic fundamentals (e.g., hitting the ball across the net etc.). Each session was supervised by graduate student investigators who provided verbal feedback and ensured the game was being played correctly and continuously during the 1-hour sessions. A make-up day was provided on two occasions over the 6 weeks to provide an opportunity for missed sessions to be made up. Sessions were a minimum of 48-hours apart. There were no missed sessions by any of the subjects across the 6-week study.

Statistics

Percent change scores were used to assess the relative changes between the pretest and posttest trials and effect sizes were calculated using Cohen's *d* statistic with values of 0.20, 0.50, and 0.80 corresponding to small, moderate, and large effect sizes, respectively. An alpha level of $p \leq .05$ was used to determine statistical significance. Bayesian pairwise comparisons were also performed to estimate the probability of a greater than zero effect size.

RESULTS

Five participants completed all Pickleball sessions during the 6-week intervention and only their data is reported (one participant only complete three weeks of the intervention and their data has been excluded from all analyses).

Knee extensor mean power increased 18.7% from 160.4 ± 31.0 W to 190.4 ± 65.1 W from the pretest to the posttest and the probability of this being a greater than zero difference is 0.724. Figure 1 shows a scatterplot of the relative change (%) for each participant for the knee extensor power variable. Figure 2 shows vertical jump height increased 7.5% from 18.7 ± 8.2 cm to 20.1 ± 7.9 cm from the pretest to the posttest. The probability of a greater than zero difference in vertical jump height is 0.596. Effect sizes were 0.63 and 0.17 for the leg power and jump height variables, respectively.

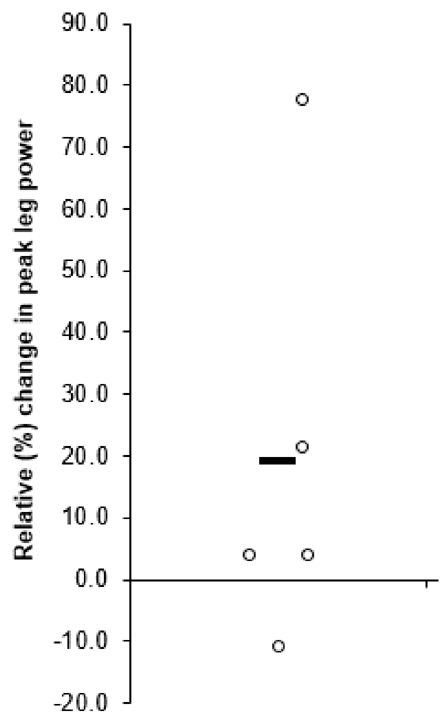

Figure 1. Relative change (%) in leg mean power output following a 6-week Pickleball intervention (n = 5). Horizontal bar = group mean.

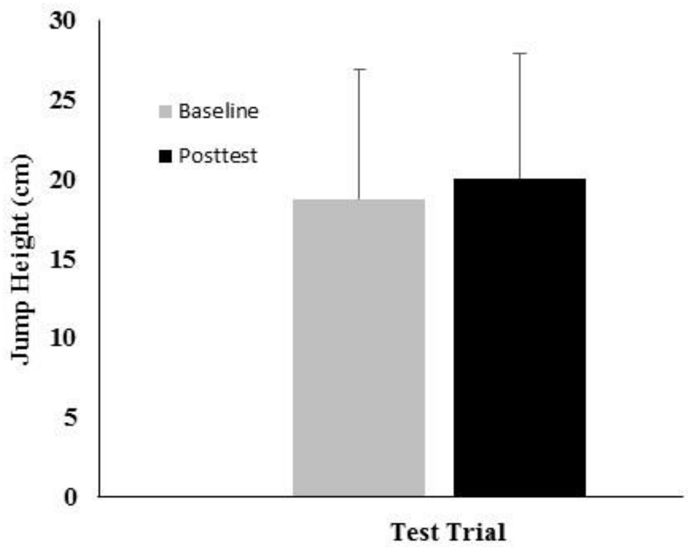

Figure 2. Vertical jump height for baseline and posttest trials. Horizontal bar = group mean. Data are mean ± SD.

DISCUSSION

This study aimed to determine if 6 weeks of playing Pickleball could improve lower body power and functional performance (vertical jump). The main findings of this study suggest that lower body power was moderately improved such that isolated knee extensor power showed a 19% gain. However, gains in vertical jump showed a smaller effect with a 7.5% increase in jump height.

The present finding showing a moderate effect for improved lower body knee extensor power from Pickleball participation is in agreement with the findings of Krustrup, et al. (2010a). These authors reported an increase in lower limb muscle strength after completing a 12-week soccer training program in healthy, untrained, males (age = 31.5 years) (Krustrup, et al., 2010). The subjects also improved in sprint performance which indicates an increase in lower body power production. In another study by Krustrup, et al. (2010b) showed improved muscle strength (16-27%) resulting from 16-months of football training in healthy, untrained, premenopausal women (age = 40 years), Moreover, Sundstrup et al. (2010) showed that1 year of football training , in healthy, elderly males (age = 68.2years) induced an 18% increase in hamstring strength and an 89% increase in rate of force development between 4 to 12 months with no improvements seen from baseline to 4 months. Taken all these findings together it appears that sport activities that require explosive lower body actions can lead to gains in muscle function in middle to older aged adult men and women in as little as 6-weeks (present study), but may take as long as 4 to 12 months to realize these benefits. The differences among the studies in the time course for achieving muscle function gains may be due to the differences in the sport activity (Pickleball vs. football), training structure, baseline training status, and muscle group assessed (quadriceps in the present study versus hamstrings in the Sundstrup et al. study). More research is needed to elucidate the specific training details that may have the greatest influence on muscle function gains. Also, follow up studies with larger sample sizes are needed to validate the present findings.

Vertical jump performance is used as a global indicator of lower body muscle function and is functionally relevant because it assesses the ability to generate power under complex, real-world, movement patterns. Therefore, it may be an important indicator of muscle dysfunction and/or frailty risk in older populations. This study showed a small effect of the Pickleball participation on vertical jump changes. However, these results should be interpreted with caution on account of the small sample size. Nonetheless, previous studies have shown an increase in vertical jump height due to playing sports such as football and soccer. For example, Sundstrup et al. (2010) reported a 50% improvement in jump height in healthy elderly males (age = 68 years), from baseline to post-testing in the football trained group compared to the control group. Haugen (2018) also showed improvement in jump height in young soccer players from pre- to postseason testing. The lower gains in jump height for the present study were likely due to the much shorter duration of the sport intervention compared to the previous studies with longer training durations. This suggests that there may be a longer duration requirement for complex movement muscle function gains compared to gains on simple isolated movements such as the seated leg extension. In addition, the reduced improvements for the vertical jump task in comparison to the isolated knee extensor power output may be partially due to differences between the movement tasks. For example, the vertical jump uses multiple muscle groups in a complex coordinated pattern whereas the seated knee extensor movement only involves an isolated muscle action. Differences between these assessment tasks also include differences in muscle group involvement. Whereas the knee extensor task only involves the anterior knee joint muscles (quadriceps), the vertical jump relies heavily on the hip extensors and plantar flexor muscles. Thus, it is possible that the change-of-direction nature of Pickleball may recruit the knee extensor muscles to a proportionally greater degree than other lower body muscle groups. Finally, the transferability of sport-based gains in performance tests may not be as high for complex movements such as the vertical jump compared to single-joint actions. Further research is needed to test these hypotheses and elucidate the specific types of tasks and muscle groups that show performance gains from regular participation in explosive sport-based activities.

Physical inactivity leads to myriad chronic illnesses and an increased risk of falls. Muscle function is important for older adults to maintain their independence and quality of life. Identifying and implementing the most optimal means for increasing lower body strength and power can more effectively attenuate that risk. These studies show that Pickleball participation can have a positive effect on muscle parameters such as strength and power and that it was overall well tolerated by this older population. In particular, Pickleball may be a promising and effective exercise/activity since it is highly accessible, cost effective, and readily available. These findings offer some support showing that it may elicit some modest gains, in a rather short duration, for lower body function which could help reduce the burdens of dysfunction such as falls, mobility, and frailty of older adults on long-term basis. However, more work is needed to corroborate these findings with larger sample sizes and longer duration interventions.

CONCLUSION

Six-weeks of Pickleball elicited a moderate effect for improving lower body quadriceps power output and a small effect for improving lower body function as measured by jump performance. Thus, 6 weeks of playing Pickleball showed some promising effects for improved muscle function, but a longer time period may be needed to realize more substantial gains in older adults. The present study showed Pickleball seemed to be a safe, enjoyable, and effective way to improve physical activity participation in older adults.

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