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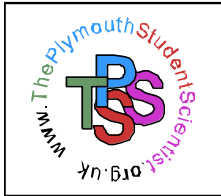
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Is Cardiovascular Health Affected by Exercise Type and Impact?

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Abstract

The principal aim of this study was to determine whether cardiovascular health, assessed by resting systolic and diastolic blood pressure and resting heart rate, was affected by exercise type (golf vs. tennis) and associated impact (low vs. high). Male and female golfers ($n = 40$) and tennis players ($n = 40$) aged between 40 and 71 years completed a short questionnaire relating to their main sport and typical exercise habits. Resting blood pressure and heart rate readings were then taken using an electronic wrist sphygmomanometer. The analysis of variance (General Linear Model) showed that overall there were no significant differences in either the resting systolic or diastolic blood pressure, or resting heart rate, of golfers and tennis players. However, a significant increase in systolic blood pressure with age ($F = 10.48$, $p = 0.002$) was observed in golfers, compared with no significant age-related increases in blood pressure in tennis players. In conclusion, exercise type and impact appear to have no effect on cardiovascular health in the 40 to 71 year olds age group, but high impact exercise may have a protective effect against age-related increases in blood pressure which requires further investigation.

Key words: Exercise; impact; golf; tennis; blood pressure; heart rate.

Introduction

Cardiovascular disease (CVD) is a major public health problem in terms of both high morbidity and mortality rates and great economic costs (British Heart Foundation 2006). Although genetic factors are known to play a part in susceptibility to CVD (Knuiman *et al.* 1996), the importance of modifiable risk factors is increasingly being recognised (Powers & Dodd 2003).

Lack of physical activity is considered one of the major risk factors for CVD (Powers & Dodd 2003). There is indisputable evidence from laboratory studies of animals (Williams *et al.* 2003) and natural studies of both leisure and occupational activity in humans (Noda *et al.* 2005; Hu *et al.* 2005) to show that regular exercise can effectively improve cardiovascular health and reduce the risk of disease.

The physiological mechanisms involved in the long-term cardiovascular benefits of exercise are not completely clear at this time and should be the focus of future research, but it is thought that exercise indirectly has a protective effect through reduction of other risk factors such as cholesterol levels and obesity (Fentem 1994). Additional possible explanations are structural adaptations of the cardiovascular system, including hypertrophy of the heart and improvements in vascular number and structure, as well as neurohumoral adaptations including alterations in vasodilators (e.g. nitric oxide) and vasoconstrictors (e.g. norepinephrine) and enhanced insulin sensitivity (Pescatello *et al.* 2004).

Blood pressure is considered a reliable measure of cardiovascular health (Kelley *et al.* 2001). Hypertension, or high blood pressure, has been linked with an increased risk of CVD, up to three times greater than that of normotensive individuals (Wang *et al.* 2006). Many studies have shown exercise to be beneficial for lowering blood pressure; for example, a meta-analysis by Whelton *et al.* (2002) found aerobic exercise to be associated with significant reductions in resting systolic and diastolic blood pressure in both hypertensive and normotensive persons. Another meta-analysis showed that walking exercise programs in adults led to reductions in blood pressure of approximately 2 % (Kelley *et al.* 2001).

Resting heart rate is another measure of cardiovascular health; an elevated heart rate has been shown to increase the risk of CVD mortality (Kristal-Boneh *et al.* 2000; Palatini 2006). Several studies have revealed that regular exercise is associated with a reduced heart rate (Houde & Melillo 2002).

Despite the existence of public guidelines for the recommended quantity of exercise (e.g. Bouchard *et al.* 1993), the methodology used in many studies has been criticised and several deficiencies in our knowledge concerning physical activity and cardiovascular health still exist. Houde and Melillo (2002) propose that sample sizes have generally been too small, and that interventions, measures of physical activity and outcomes vary widely between studies. A review of studies into the effects of walking on resting blood pressure revealed that a number of extraneous variables that could affect blood pressure were inadequately controlled for; for example, only 13 % of the studies reviewed reported the time of day that blood pressure was assessed (Kelley *et al.* 2001).

Gender and age differences in the effects of exercise on cardiovascular health have not been well researched (Pescatello *et al.* 2004). The majority of studies in this area have predominantly used men (Cox 2006), so the question arises of whether the same response to exercise can be found in women. Among the studies that have used women as participants, the results appear to be complex; while regular aerobic exercise in women has been associated with a reduced incidence of cardiovascular disease (Manson *et al.* 2002) and lowered resting blood pressure (Cox 2006), swimming in older women has been associated with increased resting systolic blood pressure (Cox 2006). A study in Finland by Hu *et al.* (2005) found that coronary heart disease risk was reduced in women, but not in men, who regularly walked or cycled to work. Another deficiency is that most studies have used participants within a limited age range (Houde & Melillo 2002), and in those that have considered age differences in the cardiovascular health benefits of exercise the results are again inconsistent. Some studies have shown that cardiovascular benefits of aerobic exercise occur independently of age (e.g. Paffenbarger *et al.* 1993; Manson *et al.* 2002), whereas there is some evidence of age-related differences in the effects of exercise on blood pressure. For example, Wei *et al.* (1987) found evidence for differential effects of exercise on resting blood pressure in

adult and aged rats, and Kelley *et al.* (2003) showed in a meta-analysis that exercise intervention did not result in reductions in the resting blood pressure of children or adolescents.

Rather than focusing on the cardiovascular health benefits of exercise in general, there is now a clear need for investigation into specific aspects of exercise – mode or type, frequency, duration and intensity (Pescatello *et al.* 2004). In particular, data on the effects of exercise type and intensity on cardiovascular health are sparse (Tanasescu *et al.* 2002). Current recommendations are based on the assumption that the same health benefits are found with all aerobic exercise (Cox 2006) but it is clear that this may not be true. For example, differential effects of exercise type on resting blood pressure have been found, with swimming producing increases in systolic blood pressure compared with walking (Cox 2006). Also, Kingwell and Jennings (1993) showed that the extent to which resting blood pressure is reduced depends on exercise type, intensity and duration, with the greatest reductions observed with moderate exercise levels. In addition, these researchers concluded that exercise led to reductions in resting heart rate, and that these reductions were proportional to exercise intensity. In contrast, other researchers maintain that all types of aerobic exercise are equally beneficial for cardiovascular health (Blair *et al.* 1992). For example, a longitudinal study by Manson *et al.* (1999) found no effect of exercise type and intensity, with walking and vigorous exercise leading to similar reductions in the risk of coronary heart disease. Whelton *et al.* (2002) found similar results, with no effect of exercise type or intensity on resting blood pressure.

This study aims to address some of the deficiencies in current research by determining whether cardiovascular health, assessed by resting systolic and diastolic blood pressure and resting heart rate, is affected by exercise type (golf vs. tennis) and associated impact (low vs. high) in the 40 to 71 year olds age group. The study also aims to establish whether gender-related or age-related differences exist within or between exercise groups, and to determine the optimum number of weekly exercise sessions.

Methods

Participants

Adult volunteers (all non-smokers) aged between 40 and 71 years, who declared they were in good health and not currently taking any long-term blood pressure medication, were invited to take part. Qualifying participants had a main declared sport that was either golf or tennis, exercised regularly (at least twice weekly), and had engaged in this sport for at least one month (the minimum time required for exercise to lower resting blood pressure – Jennings *et al.* 1986). 40 golfers and 40 tennis players were included in the study. An equal number of males and females were recruited for each sport. Participants were also divided into two equal age groups; the purpose of this was to facilitate data analysis and to determine whether exercise type differentially affected the cardiovascular health of middle-aged (40 to 55) and older (56 to 71) adults.

Procedure

Ethical approval for the study was obtained from the Faculty of Science's Human Ethics Committee, at the University of Plymouth. Prior to data collection, a pilot study was conducted with six volunteers but no alterations to the procedure were necessary.

Participants first completed a short questionnaire relating to their main sport, exercise frequency and duration, as well as reasons for taking part in this sport, and the emotional and physical benefits (a sample questionnaire is shown in Figure 1). Resting blood pressure and heart rate readings were then taken, using an electronic wrist sphygmomanometer (Balance KH 8097), and recorded on the questionnaire. Participants were seated and asked to present a wrist from which readings could be taken. The arm was supported at the level of the heart, and participants were informed to relax and refrain from talking during blood pressure and heart rate measurements. Readings were taken before exercise in order to prevent a post-exercise hypotension effect (Bouchard *et al.* 1993). As time of day causes large variations in blood pressure (Millar-Craig *et al.* 1978), all data was collected between 1.00 and 3.00 pm. A verbal debriefing was given to all participants before and after

data collection, but participants were only informed of their heart rate and blood pressure readings if requested. In this case, if blood pressure was revealed to be abnormally high or low, the individual was encouraged to seek additional medical advice.

Project Investigation:
Is cardiovascular health affected by exercise type & impact?

Please tick the box if the following statement applies to you:
"I am generally in good health and am not currently taking any blood pressure medication"

1. Age: _____ Gender: Male Female

2. Do you smoke? Yes No

3. Do you have a main sport? (i.e. one particular sport you spend more time on than any other)
Yes No

If yes, what is your main sport? Golf Tennis Other

If other, please identify: _____

4. How many times a week do you usually play your main sport?
(please circle as appropriate)

1 2 3 4 5 More than 5

5. On average, how many hours a week would you say you spend on your main sport?
(please circle)

1 to 2 3 to 4 5 to 6 7 to 8 9 to 10 More than 10

6. For how long have you regularly played this sport? (please circle)

Less than 1 month 1 to 5 months 6 to 12 months 1 to 2 years

2 to 3 years 3 to 4 years 4 to 5 years More than 5 years

7. What is the most important reason to you for taking part in your main sport?
(please tick one only)

Socialising/pleasure To improve my health/fitness Other

If other, please identify: _____

Please turn over...

Figure 1a: Sample questionnaire (completed by participants before blood pressure and heart rate readings)

**8. Do you feel better EMOTIONALLY after taking part in your sport?
(please circle)**

Yes No

**9. Do you feel better PHYSICALLY after taking part in your sport?
(please circle)**

Yes No

Thank you very much for your participation.

TO BE COMPLETED BY EXPERIMENTER:

Heart rate: _____ bpm.

Blood pressure: mm Hg
 SYSTOLIC
 mm Hg
 DIASTOLIC

Figure 1b: Sample questionnaire – page 2

Statistical Analyses

All statistical analyses were carried out using the computer software 'MINITAB'. Firstly, Levene's test for equal variances was performed on all blood pressure and heart rate data in order to check homogeneity of variance. A 3-factor analysis of variance, or ANOVA (General Linear Model) was used to determine whether exercise type (main sport), age group and gender had an effect on resting systolic blood pressure, resting diastolic blood pressure, and resting heart rate. All possible interactions were also checked in the ANOVA. A one-way ANOVA (with Tukey's follow-up analysis) was performed to determine whether the number of weekly exercise sessions (i.e. exercise frequency) had an effect on resting blood pressure and heart rate. Finally, the General Linear Model (with 'age of golfers' and 'age of tennis players' as covariates) was used to establish whether exercise type

interacted with age in determining resting blood pressure and heart rate. All data analysis was performed at the 5 % significance level.

Results

Participants and Exercise Characteristics

88 participants in total were recruited, and eight of these were excluded from the study (reasons included smoking, age outside required range, temporal arteritis, and failure to exercise at least twice weekly). The number of participants that met the inclusion criteria are shown in Table 1.

Table 1: Number of participants included in study (total $n = 80$)

	Golfers ($n = 40$)		Tennis Players ($n = 40$)	
	Male	Female	Male	Female
40-55	$n = 10$	$n = 10$	$n = 10$	$n = 10$
56-71	$n = 10$	$n = 10$	$n = 10$	$n = 10$

Participants were closely matched in terms of age; the mean age of those with golf as a main sport was 57.5 years (standard error of mean, SEM, ± 1.62) and the mean age of those with tennis as a main sport was 56.1 years (SEM ± 1.37). Exercise frequency was also well matched between exercise groups; the most common (mode) number of weekly exercise sessions was two for both golfers and tennis players. However, the weekly exercise duration varied between exercise groups (mode weekly duration = More than 10 hours for golfers, 3 to 4 hours for tennis players).

Results of Levene's Test

Levene's test confirmed homogeneity of variance for all data (all p -values > 0.1), allowing the ANOVA to be performed without any transformation.

Does Exercise Type and Associated Impact Have an Effect on Resting Blood Pressure or Resting Heart Rate?

Although mean resting blood pressure appeared to be slightly higher in golfers (see Table 2), the ANOVA revealed that there were no significant differences in either the systolic or diastolic blood pressure of golfers and tennis players ($F = 1.09$, $p = 0.30$ for systolic; $F = 0.03$, $p = 0.87$ for diastolic). There was also no significant difference in the mean resting heart rate (shown in Table 2) of golfers and tennis players ($F = 0.36$, $p = 0.55$). These results suggest that exercise type and associated impact have no effect on resting blood pressure or heart rate.

Table 2: Mean resting heart rate and systolic and diastolic blood pressure in golfers and tennis players aged 40-71 years

	Mean Heart Rate (beats/min)	Mean Systolic Blood Pressure (mm Hg)	Mean Diastolic Blood Pressure (mm Hg)
Golfers ($n = 40$)	75.10 (± 1.53)	158.90 (± 4.83)	98.55 (± 2.96)
Tennis Players ($n = 40$)	76.55 (± 1.88)	153.07 (± 4.35)	97.93 (± 2.93)

Standard error of mean (SEM) is shown in brackets.

Do Gender-Related Differences Exist Within or Between Exercise Groups?

The ANOVA showed that gender had no effect on resting heart rate ($F = 0.55, p = 0.46$), and there was no evidence for an interaction between gender and exercise type in determining resting heart rate ($F = 0.55, p = 0.46$).

There were significant gender differences in resting systolic ($F = 19.33, p < 0.001$) and diastolic ($F = 12.86, p = 0.001$) blood pressure, with mean blood pressure being higher in males than females (as shown in Table 3). However, there was no evidence for an interaction between gender and exercise type in determining either systolic ($F = <0.01, p = 0.99$) or diastolic ($F = 0.13, p = 0.72$) blood pressure.

Table 3: Gender differences in resting systolic and diastolic blood pressure in golfers and tennis players aged 40-71 years

Gender	Mean Systolic Blood Pressure (mm Hg)	Mean Diastolic Blood Pressure (mm Hg)
Male ($n = 40$)	168.28 (± 4.5)	105.17 (± 2.6)
Female ($n = 40$)	143.70 (± 3.8)	91.30 (± 2.8)

Standard error of mean (SEM) is shown in brackets.

Do Age-Related Differences Exist Within or Between Exercise Groups?

The ANOVA revealed that there were no statistically significant differences in resting heart rate between the two main age groups ($F = 2.20, p = 0.14$), and there was also no interaction between age group and exercise type in determining resting heart rate ($F = 0.55, p = 0.46$).

There was strong evidence for a difference in resting systolic blood pressure between the two age groups ($F = 11.10$, $p = 0.001$), with systolic blood pressure being higher in the upper age group (see Table 4). The difference in resting diastolic blood pressure between these age groups was not significant ($F = 3.39$, $p = 0.07$).

Table 4: Age-related differences in resting systolic and diastolic blood pressure in golfers and tennis players

Age group	Mean Systolic Blood Pressure (mm Hg)	Mean Diastolic Blood Pressure (mm Hg)
40 - 55 ($n = 40$)	146.68 (± 4.2)	94.68 (± 2.8)
56 - 71 ($n = 40$)	165.30 (± 4.5)	101.80 (± 3.0)

Standard error of mean (SEM) is shown in brackets.

The initial ANOVA found no significant interaction between age group and exercise type in determining either resting systolic ($F = 1.22$, $p = 0.27$) or diastolic ($F = 0.26$, $p = 0.61$) blood pressure. However, further analysis suggested that there might in fact be some interaction between exercise type and age in determining resting blood pressure. By fitting a regression line to a scatterplot of the data, a large increase in systolic blood pressure with age could be seen in the golfers compared with only a slight increase with age in tennis players (as shown in Figure 2). The General Linear Model showed that this increase in systolic blood pressure with age was significant in golfers ($F = 10.48$, $p = 0.002$) but not in tennis players ($F = 0.29$, $p = 0.59$). A similar increase in diastolic blood pressure with age was also observed in golfers, compared with a slight decrease with age in tennis players (see Figure 3). However, the changes in diastolic blood pressure with age were revealed to be non-

significant for both golfers ($F = 3.54, p = 0.06$) and tennis players ($F = 0.01, p = 0.93$).

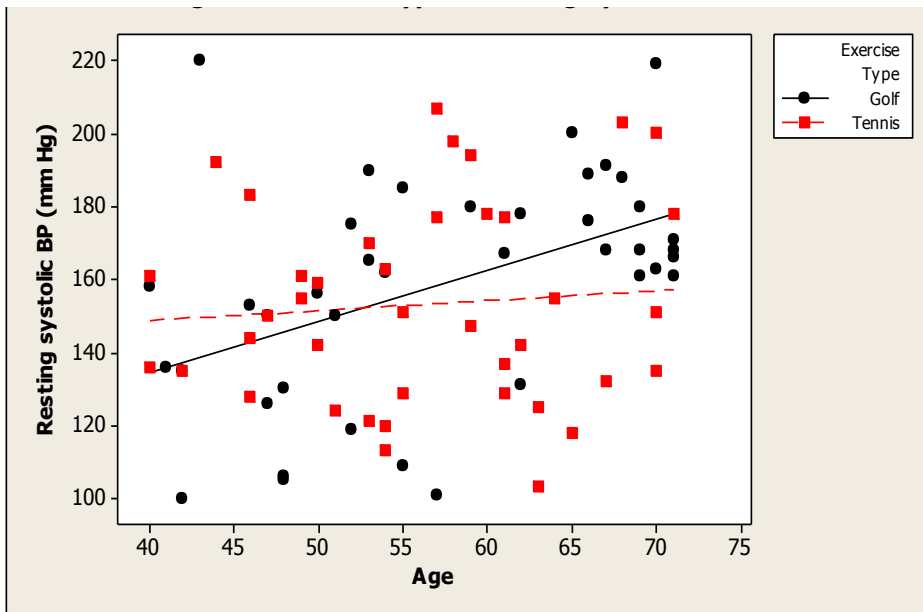


Figure 2: Scatterplot with regression to show the effect of age and exercise type on resting systolic blood pressure

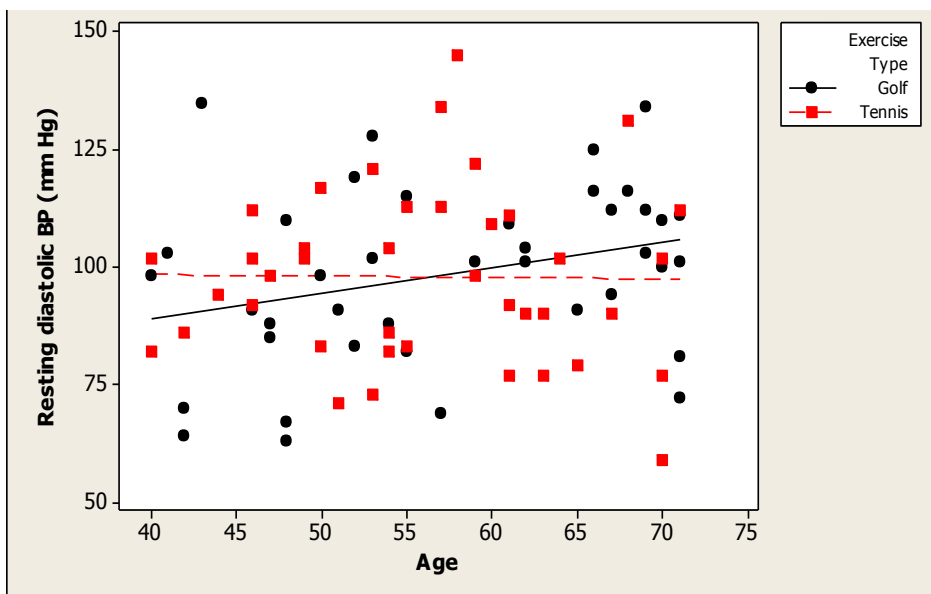


Figure 3: Scatterplot with regression to show the effect of age and exercise type on resting diastolic blood pressure

No significant association between age and resting heart rate was found for either golfers ($F = 1.56, p = 0.22$) or tennis players ($F = 1.18, p = 0.28$).

Does Exercise Frequency (Number of Weekly Exercise Sessions) Have an Effect on Resting Blood Pressure or Resting Heart Rate?

Combining the data from golfers and tennis players in order to determine whether there was an overall effect of exercise frequency, the one-way ANOVA showed that number of weekly exercise sessions did not significantly affect resting heart rate ($F = 0.23, p = 0.87$) or resting blood pressure ($F = 0.63, p = 0.60$ for systolic; $F = 1.17, p = 0.33$ for diastolic). However, an interesting trend emerged from the available data, with both resting systolic and diastolic blood pressure increasing with exercise frequency up to the point of four weekly exercise sessions, but the lowest mean resting blood pressure was associated with five weekly sessions of golf or tennis (as shown in Figure 4).

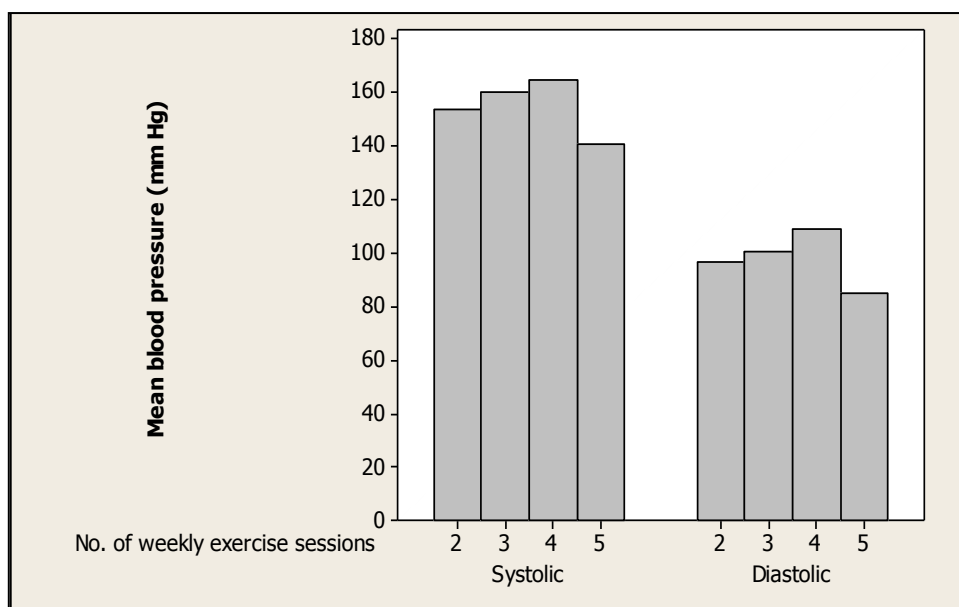


Figure 4: The effect of exercise frequency on resting blood pressure in golfers and tennis players aged 40-71 years

Other Observations and the Reported Benefits of Exercise

When asked how long they had regularly played their main sport, a greater proportion of golfers (80 %) than tennis players (55 %) selected “More than 5 years”. Concerning the main reason for participating in sport, 83 % of golfers selected “Socialising/pleasure”, compared with 60 % of tennis players. Improvement of health and fitness provided greater motivation for tennis players than golfers, with 38 % of tennis players selecting this as the main reason for participation compared with only 15 % of golfers (see Figure 5).

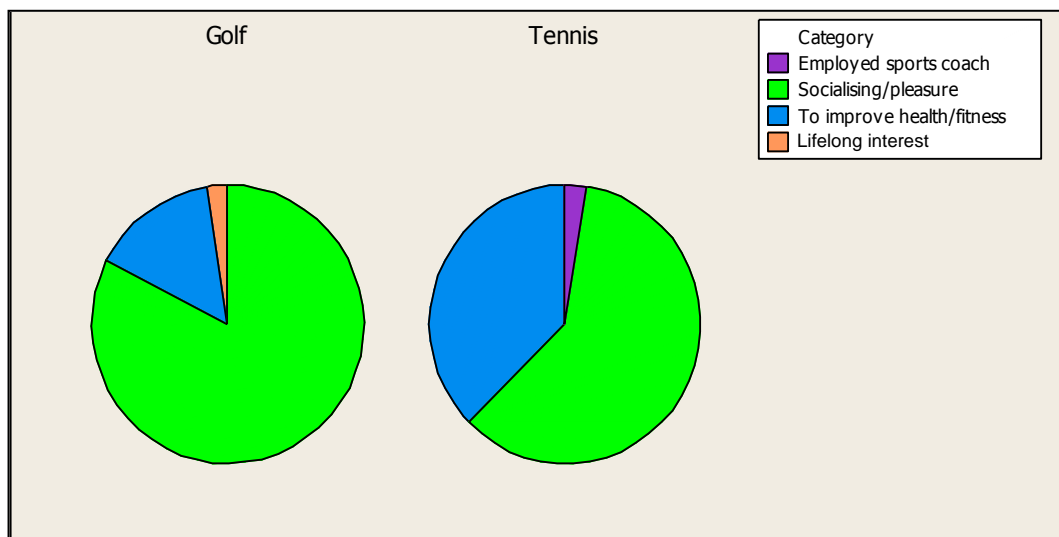


Figure 5: Most important reason for taking part in golf or tennis
(participants were asked to select one reason only)

The majority of participants believed that taking part in their main sport led to both physical and psychological health benefits. An equal proportion of golfers and tennis players (90 %) reported feeling better emotionally after exercise. However, there was some evidence that low impact exercise is associated with better self-reported physical health than high impact exercise; 95 % of golfers stated that they felt better physically after playing their sport, compared with 78 % of tennis players.

Discussion

The overall results of this study suggest that exercise type (golf vs. tennis) and associated impact (low vs. high) do not significantly affect resting blood pressure or resting heart rate in the 40 to 71 year olds age group. These findings are in agreement with Whelton *et al.* (2002), who considered several types of aerobic exercise in a meta-analysis and found no significant effect of exercise type on resting blood pressure. The results are also consistent with those of Manson *et al.* (1999), who found that both walking and vigorous exercise led to similar reductions in coronary heart disease risk. The general results do not support the conclusion made by Cox (2006) that exercise type can produce differential changes in resting blood pressure.

Despite the lack of significance of the overall results, further analysis revealed that there was an interaction between exercise type and age in determining resting systolic blood pressure, with a significant increase in systolic blood pressure with age observed in golfers but not in tennis players. A possible interpretation of these results is that tennis, a high impact form of exercise, has a protective effect against age-related increases in blood pressure that cannot be achieved with low impact exercise such as golf. Regular exercise has been shown to minimise the detrimental effects of aging on cardiac performance and attenuate the age-related rise in blood pressure (Fentem 1994), and it is feasible that this can be achieved only by high impact exercise. This interpretation should be made with caution, however, as an alternative explanation is that adults with lower blood pressure may have healthier lifestyles in general and are therefore more attracted to high impact sports such as tennis. Indeed, this was reflected in the questionnaire results, which showed that a greater proportion of tennis players (38 %) than golfers (15 %) were principally concerned with improving their health and fitness. Nevertheless, this possible interaction between age and exercise type in determining resting blood pressure is a novel finding that requires further research. Although previous studies have found evidence to suggest that there are age-related differential effects of exercise on resting blood pressure (e.g. Wei *et al.* 1987), none appear to have examined how aspects of exercise, such as type, can moderate these effects.

Even after further analysis, no evidence for age-related changes in resting heart rate in either the golfers or tennis players was found, again suggesting that exercise type has no effect on resting heart rate. This finding is contrary to that reported by Kingwell and Jennings (1993), who suggested that the effects of exercise on resting heart rate vary according to exercise type and intensity. However, these researchers conducted a single study with an extremely small sample of 14 participants, so it is reasonable to question the validity of their conclusion.

No gender differences in resting blood pressure or resting heart rate were found between exercise groups, i.e. there appears to be no interaction between exercise type and gender in determining cardiovascular health. However, there were significant differences in the resting blood pressure of males and females overall, with substantially higher blood pressure in males, which is a typical finding (Perusse *et al.* 1991).

No effect of exercise frequency on resting blood pressure or resting heart rate was found for golfers or tennis players, with no significant differences in the systolic or diastolic blood pressure or heart rate in those who exercised two, three, four, or five times weekly. These results do not support evidence for the dose-response relationship reported by Warburton *et al.* (2006), in which the highest levels of physical activity were associated with the lowest risk of cardiovascular disease. Furthermore, the results do not correspond to current exercise guidelines, which emphasise the importance of an exercise frequency of five to seven sessions per week for optimal cardiovascular health benefits (Myers 2003). However, an interesting trend was observed, with mean resting systolic and diastolic blood pressure increasing slightly with exercise frequency up to the point of four weekly exercise sessions, but the lowest mean resting blood pressure was associated with five weekly exercise sessions.

Although not the primary focus of the study, both physical and psychological health benefits of participation in sport were reported by the majority of golfers and tennis players. Such benefits are well documented; for example, Shin (1999) reported significantly improved physical function and emotional state in elderly

females following participation in a low impact exercise programme. Similarly, a study by DiLorenzo *et al.* (1999) found that regular exercise (of varying intensities) led to improvements in physical fitness and associated this with a number of positive psychological outcomes in both the short and long term. Exercise has also been associated with reduced depression and lower levels of the stress hormones cortisol and epinephrine (Nabkasorn *et al.* 2005). The link between psychological factors and cardiovascular health is currently unclear, but stress has been significantly associated with cardiovascular morbidity and mortality (Everson-Rose & Lewis 2005). It is thought that prolonged activation of the sympathetic nervous system as a result of stress can adversely affect the cardiovascular system, and stress can also have an indirect effect on cardiovascular health via behavioural changes such as increased smoking (Macleod *et al.* 2002).

Despite the health benefits of exercise being reported by the majority of participants, it was observed that those who engaged in high impact exercise were less likely than the low impact group to report feeling better physically after exercise. This may reflect the increased risk of physical injury and joint problems that has been associated with high impact exercise compared with low impact exercise (Conaghan 2002). The results also indicated that people may be more likely to persevere with low impact rather than high impact exercise, with a higher percentage of golfers than tennis players reporting having regularly participated in their sport for longer than five years.

Conclusion

Overall, this study found no significant difference in the resting blood pressure or resting heart rate of golfers and tennis players. However, the results suggested that there was some interaction between age and exercise type in determining resting blood pressure, with a significant increase in systolic blood pressure with age observed in golfers but not in tennis players. This may indicate that high impact forms of exercise, such as tennis, have a protective effect against age-related increases in blood pressure that cannot be achieved with low impact exercise such as golf. There were no age-related changes in resting heart rate in either golfers or

tennis players, and there were no gender-related differences in the effects of exercise type on resting blood pressure or resting heart rate. Physical and psychological health benefits of exercise were reported by the majority of golfers and tennis players, but those who participated in high impact exercise (tennis) were less likely to report feeling better physically after exercise. No significant effect of exercise frequency on either resting blood pressure or resting heart rate was found in golfers and tennis players.

Recommendations

Recommended levels of exercise:

As a result of this study and related studies, it is recommended that male and female adults take part in regular aerobic exercise, at least twice weekly, for a minimum duration of 30 minutes per session. All types of exercise appear to be beneficial for health. Low impact sports (such as golf) and high impact sports (such as tennis) confer similar benefits to cardiovascular health (as well as psychological health), but participating in a high impact sport twice weekly may have additional benefits for lowering blood pressure in older adults.

Blood pressure tests at sports clubs:

Mean blood pressure was found to be above the normal range for both golfers and tennis players in the 40 to 71 year olds age group, and importantly many participants were unaware that they may have hypertension. Furthermore, the opportunity for blood pressure measurement was well received by the majority at the golf and tennis clubs. Therefore it is recommended that blood pressure tests carried out by medical professionals are made available at sports clubs in the future, and clear information and advice should be provided in order to improve public awareness of hypertension, its health implications, and ways in which it can be controlled.

Limitations and Improvements

The sample that was used in this study (80 participants) is relatively small. This may be one of the reasons for the lack of significant findings relating to, for example, the effect of exercise frequency. A larger sample size would have improved the power of all statistical tests used for data analysis.

Although the study was well controlled in general, with golfers and tennis players being effectively matched in terms of age, general health and exercise frequency, the mode weekly exercise duration was considerably greater for golfers than tennis players. This difference simply reflects the greater duration of a typical round of golf compared with a typical tennis match, and would have been difficult to control without intervention.

A major limitation was the inclusion of a number of participants who played more than one sport, and in some cases a combination of high and low impact sports. An improvement would be to include participants who take part in only one sport, rather than those who have a main sport. However, recruitment of such participants with only one type of exercise would have been more difficult and would have limited the sample size further.

Concerning the measurement of blood pressure, the wrist from which readings were taken (left or right) was varied between participants. It has been shown that blood pressure data can vary between an individual's right and left arm, with a tendency for both systolic and diastolic blood pressure to be slightly higher in the right arm (O'Shea & Murphy 2000). This is another factor that should be controlled in future studies. Furthermore, only one resting blood pressure and heart rate reading was taken for each participant. The use of more than one measurement and calculation of an average would have given more precise results, but this was prevented by time constraints and it would be unreasonable to expect volunteers to engage in such a procedure.

It is possible to criticise the study on the grounds of the use of retrospective self-report to determine participants' exercise levels. Some studies have shown that self-report can be biased (e.g. Macleod *et al.* 2002). Alternative measures, such as

prospective studies with direct monitoring of exercise levels, may be more reliable, but this was not practicable for the current study.

The inclusion of a control group of participants who take no regular exercise is another possible improvement. This would allow the extent of cardiovascular health benefits of the two types of exercise to be determined.

Further Investigations

It is clear that further analysis of the interaction between age and exercise type in determining resting blood pressure is needed. This can be achieved by studying the effects of exercise type for a wider age range, ideally with longitudinal investigations that follow a cohort of participants over time.

Future studies should consider the effects of a number of alternative sports and types of exercise on cardiovascular health. For example, cycling (low impact exercise) could be compared with dance (high impact exercise). Moderate impact forms of exercise (such as cricket) could also be investigated, and a comparison of the effects of different exercise types within the low, moderate, or high impact category is a further possibility.

Alternative measures of cardiovascular health should be used in future investigations into the effects of various types of exercise. In addition to resting blood pressure and heart rate, morbidity and mortality from cardiovascular disease, as well as risk factors for cardiovascular disease, such as body mass index and blood cholesterol levels, could be assessed.

Other areas of potential research include the short-term, acute effects of different exercise types on blood pressure and heart rate, which would involve taking readings before and immediately after exercise. Furthermore, it should be determined whether type and impact of exercise have differential effects on cardiovascular health in normotensive and hypertensive individuals.

Further research is necessary to determine the intensity, frequency and duration of different types of exercise that is needed for optimal cardiovascular

health benefits. As a result of future findings, exercise recommendations should be updated to include specific programmes aimed at particular age groups and genders.

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