**Title: The Musculoskeletal Health Benefits of Tennis.**

**Abstract**

**Background:** The prevalence of musculoskeletal (MSK) conditions is increasing and although current guidelines for physical activity attempt to combat this, many fail to achieve the recommended targets. The present study, sought to investigate whether regular tennis participation is more effective at enhancing MSK function, than meeting the current international physical activity guidelines.

**Hypothesis:** Tennis players will display significantly enhanced MSK function when compared to age-matched healthy active non-players.

**Study Design:** Cross-sectional study.

**Level of Evidence:** Level 3.

**Methods:** 90 participants, aged 18-65 years, took part in this study 43 tennis players (18 ♂, 25 ♀) and 47 non-players (26 ♂, 21 ♀). MSK function was assessed by cluster analysis of 3 factors: 1. EMG fatigability of prime movers during handgrip, knee extension and knee flexion 2. Isometric strength in the aforementioned movements and 3. Body composition measured by bio-electrical impedance analysis. Maximal oxygen uptake was also assessed to characterise cardio-respiratory fitness.

**Results:** Tennis players displayed significantly greater upper body musculoskeletal function than non-players when cluster scores of body fat percentage, handgrip strength and flexor carpi radialis fatigue were compared by ANCOVA, using age as a covariate (tennis players = 0.33 ± 1.93 vs. non-players = -0.26 ± 1.66, *P* < 0.05). Similarly, tennis players also demonstrated greater lower extremity function in a cluster of body fat percentage, knee extension strength and rectus femoris fatigue (tennis players = 0.17 ± 1.76 vs. non-players = -0.16 ± 1.70, *P* < 0.05).

**Conclusion:** The present study offers support for improved MSK functionality in tennis players when compared to age-match healthy active non-players. This may be due to the hybrid high intensity interval training nature of tennis.

**Clinical Relevance:** The findings suggest tennis is an excellent activity mode to promote MSK health and should therefore be more frequently recommended as a viable alternative to existing physical activity guidelines.

**Keywords:** Tennis, Health, Musculoskeletal Function, Cluster Analysis, Physical Activity

**Introduction**

There is overwhelming evidence to suggest that leading an active lifestyle is associated with health benefits and the more time spent active, the lower the risk of all-cause mortality 23. However, many fail to heed this advice and do not reach the minimum recommended 150 minutes of physical activity per week; in fact, globally an estimated 31% of adults are categorised as physically inactive, with percentages seemingly greater in high-income countries and older adults in particular, irrespective of region 17. Additionally, with increases in sedentary behaviour, the prevalence of conditions associated with poor musculoskeletal (MSK) health is also on the rise 33. Sarcopenia is one such condition and is the term given to age-related loss of muscle mass, where functional capacity and thus quality of life is drastically reduced 10. It is not uncommon to see losses of between 30 to 50% muscle mass from the ages of 40 to 80 years 11. Furthermore, osteoporosis is another such condition, characterised by low bone mineral density and increased risk of fractures, significantly associated with morbidity 25. Having said this, it is clear that physically active individuals display healthier body mass, composition and bone density; greater strength and muscular endurance; higher levels of cardiorespiratory fitness and overall superior functionality, significantly reducing their risk of developing either sarcopenia or osteoporosis in later life 38. Crucially, adopting an active lifestyle is integral to maintaining optimal MSK health across the lifespan.

To combat the ever increasing rates of MSK conditions, exercise is invariably prescribed by practitioners but often with little underlying research, ambiguous recommendations and hence, mixed results 29. This highlights the need for more realistic and sustainable physical activity interventions that can readily promote MSK health outcomes across the lifespan 9. What is known, is that optimal exercise prescription should integrate aerobic, muscle strengthening, and flexibility exercises 8. Previous literature has also commented on the particular effectiveness of group based training interventions for adults which result in higher levels of exercise adherence and programme compliance 18.

Tennis is one such activity that can incorporate these different modes of aerobic and muscle strengthening exercise, due to the nature of play and the combination of skills required, all in a group based environment. Nonetheless, at present there is a distinct lack of research analysing the impact of tennis on MSK health in particular, despite its previously documented wide ranging health benefits16. In a review of the existing literature on the subject, Pluim et al. 30 draw on several cross-sectional studies comparing tennis players to age matched controls, and detail superior body composition and bone mineral density in tennis players. However, comparisons groups in these studies did vary in their level of activity, from moderately active to completely sedentary. In line with these findings, Marks 24 also reported greater handgrip and knee extensor/flexor strength in a review of the health benefits for veteran tennis players, although not all studies came to the same conclusion, as once again lifestyle factors differed between reports. To add to this, Laforest et al. 22 not only demonstrated greater strength in their tennis players when compared to a sedentary population, but also greater resistance to fatigue, ascertained by electromyographic (EMG) testing and isokinetic dynamometry. Finally, in a recent epidemiological study of over 80,000 UK residents, participation in racquet sports was strongly associated with the greatest risk reduction in all-cause mortality, more than any other sport listed 27. However, with no distinction between racquet sports in this latter study and no attempt to elucidate the mechanisms behind their effectiveness, further research is warranted to examine tennis’s potential to enhance physical function, improve quality of life and reduce risk of developing MSK dysfunction.

Thus, the aim of the present study was to investigate whether individuals who play regular tennis have superior overall MSK health, than those currently attaining the international physical activity guidelines through other means. To this purpose, a variety of key markers of physical functioning were measured and compared between a group of tennis players and a group of age-matched healthy active non-players. It was hypothesised that the tennis players would display significantly improved MSK function than their non-playing counterparts.

**Methods**

*Participants*

Sample size was determined using G\*Power Software 12 and 80% power with α error probability of 0.05 (two-tailed), based on previous works by Swank et al.35, detailing significantly lower body fat percentage in tennis players vs. age matched moderately active non-players. Henceforth, a sample size ≥ 42 participants per group was required to observe a significant difference. In order to ensure this was obtained slightly more than this number were recruited and ultimately, 90 participants of mixed gender (male (♂) =44, female (♀) =46), aged between 18 and 65 years, took part in the study. Descriptive characteristics of the study population are presented in Table 1. All participants were recruited from the North West area of the United Kingdom. Tennis players (n=43, 18♂, 25♀) were recruited primarily through the Liverpool and District Tennis Group and had an average of 19.96 ± 15.90 years of playing experience. When questioned, all but 3 players stated they engaged in year round tennis, most of which was doubles play and only occasional singles practice. Notably, all tennis players who volunteered to take part in this study were recreational players and despite playing competitively in local leagues, none were elite. For comparison, a group of age-matched healthy active non-players (n=47, 26♂, 21♀) were recruited from within the same region. All non-players were healthy with no current health complaints or co-morbidities, and although from a mixture of sporting backgrounds, all were physically active (at least performing the globally recommended 150 minutes of moderate intensity exercise a week 38) indicated by their responses to the International Physical Activity Questionnaire – Short Form (IPAQ-SF) (data presented in table 2).

*Design*

The study was designed in accordance with the recommended guidelines for ethical practice set out by the Declaration of Helsinki and ethical approval was granted by the institutional review board. All participants were provided with an information sheet, stating all procedures, and once satisfied all gave a written informed consent. Participants were then required to complete a Physical Activity Readiness Questionnaire (PARQ) confirming no contraindications to exercise. All procedures were completed in one visit to the School of Health Sciences laboratories over the course of approximately 2.5 hours and all experiments were performed by a single experimenter. Finally, participants were instructed to arrive non-fasted but abstaining from food consumption in the 2 hours prior, and having not performed any strenuous physical exertion or consumed any alcohol or caffeine in the 24 hour period before testing.

*Anthropometry*

Participants’ height and weight were measured by stadiometer and mechanical measuring scales, followed by waist and hip measurements using ergonomic circumference measuring tape (Seca, Hamburg, Germany). Body mass index (BMI) and waist:hip ratio (WHR) were calculated from the above measurements. Bioelectrical impedance analysis (Bioscan 920-II, Maltron International Ltd., Rayleigh, Essex, UK) was then used to further assess body composition. According to the manufacturer guidelines, after 5 minutes of rest in a supine position, electrodes were placed down the right side of the body: on the dorsal aspect of the hand, over the third metatarsal and between the styloid process of the radius and ulnar, and on the dorsal aspect of the foot, over the third metatarsal and between the medial and lateral malleolus. Body composition values were computed by accompanying software BioScan 920 v1.1 (Maltron International Ltd).

*Dynamometry*

Handgrip strength, as primary measure of upper body strength, was measured on the dominant side by a wireless Jamar dynamometer (E-LINK, Biometrics Ltd., Newport, UK) in a seated upright position with the elbow flexed at 90o and the wrist in a neutral position. After familiarisation, participants were instructed to perform 3 maximal efforts for 5 seconds, with verbal encouragement and a 30 second rest period in between measurements. The mean of the 3 trials was recorded as maximal voluntary contraction (MVC).

To assess lower body strength, maximal isometric knee extension and flexion forces were measured using a portable fixed dynamometer (Myometer, Mecmesin Ltd., Slinfold, West Sussex, UK). The dynamometer was secured to a fixed stanchion and a strap was looped around the ankle, just above the lateral malleolus; participants remained seated upright whilst grasping the underside of the chair with the knee flexed at 90o. Although the position of the chair was adjusted 180o between knee extension and flexion, body position remained the same. Following familiarisation, 3 MVCs were performed on the dominant side, each for 5 seconds with verbal encouragement and 30 seconds rest between trials. As with handgrip, the mean across the 3 trials was recorded as MVC for both knee extension and flexion.

*Electromyography (EMG)*

EMG was recorded to measure the fatigability of key muscles during the upper and lower body isometric exercises outlined above, following methods previously published by Hawkes et al. 19. Participants were asked to maintain submaximal voluntary contractions at 25% of the previously measured respective MVCs in handgrip, knee extension and flexion, for 1 minute and 10 seconds (the first and last 5 seconds were excluded from analysis). As with MVC measurements, subjects were instructed to maintain the same positions in each type of contraction. In order to ensure 25% of MVC was held constant, visual feedback was provided to participants by respective software of the handgrip dynamometer and myometer (E-LINK version 14.02, Biometrics Ltd.; Emperor Lite version 1.18-408, Mecmesin Ltd.). EMG activity was recorded from the main agonists during each movement; flexor carpi radialis during handgrip, rectus femoris during knee extension and biceps femoris during knee flexion. After skin preparation, disposable, self-adhesive Ag/AgCl bipolar surface electrodes with 10mm conducting area and 20mm inter-electrode distance (Noraxon Inc.) were used to record EMG. Electrodes were placed parallel to muscle fibres on the belly of the muscles previously identified and following accepted anatomical criteria 3, signals were confirmed by manual muscle testing. A Telemyo DTS system (Noraxon Inc., Scottsdale, Arizona, USA) and MyoResearch software (Version 3.8, Noraxon Inc.) were used for signal acquisition and data analysis, respectively. Signals were differentially amplified (CMRR > 100 dB; input impedance > 100 Mohm; gain 500dB), digitised at a sampling rate of 1500 Hz and band-pass filtered at 10-500 Hz.

Fatigability of each muscle was quantified by calculating median frequency (MDF) in 1 second intervals across the 60 seconds of sustained submaximal isometric contraction at 25% MVC. A Fast Fourier Transformation was performed to allow analysis of the power spectrum. MDF was then normalised relative to starting value and the mean rate of change, assessed by linear regression, was used as a fatigue index.

*Maximal oxygen uptake*

Maximal oxygen uptake (VO2MAX) was assessed by an incremental test to exhaustion using a treadmill (h/p/cosmos, Munich, Germany) and a standard Bruce protocol 6. Indirect calorimetry was performed using a breath by breath analyser (Ergostik, Geratherm Respiratory GmbH, Bad Kissingen, Germany), calibrated prior to test. Participants’ heart rate was also monitored during the entire protocol (FR70, Garmin International Inc., Olathe, Kansas, USA). VO2MAX was considered at the observation of a plateau in VO2 or the point of volitional exhaustion. If a plateau was not reached VO2MAX was considered where either respiratory exchange ratio > 1.15, heart rate within 10 beats of age predicted maximum (220 – age) or rating of perceived exertion > 19 5.

*Statistical analyses*

Data are presented as means ± standard deviation (SD) or standard error of the mean (SEM) as appropriate. All variables were first analysed between tennis players and non-players by independent samples *t*-tests, following tests for normal distribution and transformations where data was non-normal. Additionally, in limited cases where a normal distribution was not achievable, a non-parametric Mann-Witney U test has been employed in place of a *t*-test. To analyse any potential gender differences, the above analysis was repeated in male and female participants separately.

Overall MSK function was analysed via a cluster based approach following the techniques set out by Andersen and colleagues 2. Variables were selected to represent 3 contributing factors towards overall MSK function, as identified by Cawthon et al. 7: factor 1, adiposity component, factor 2, relative strength component and factor 3, physical performance component. Furthermore, it was decided to calculate a separate score for upper and lower body function, and in both cases body fat percentage was chosen to signify the adiposity component (factor 1). Handgrip strength and knee extensor/flexor strength were selected to represent factor 2, in the upper and lower extremity, respectively. Finally, factor 3 was characterised by muscle fatigue index for the primary muscles during either handgrip, knee extension or knee flexion, to match factor 2.

All selected variables were then converted to gender-specific z-scores and to ensure each factor had the same directional weighting, body fat percentage was multiplied by -1 to convert scores to a positive weighting. Cluster scores for both upper and lower body MSK function were then calculated by the summation of their respective factors, where the greater the cluster score, the greater the MSK health or physical function was assumed. Lastly, to analyse the differences between tennis players and non-players, groups were compared by the analysis of covariance (ANCOVA), using age as a covariate. Statistical significance was set at *P* < 0.05. All analyses were performed in SPSS version 24 (IBM, New York, USA).

**Results**

No significant differences (*P* > 0.05) were observed for the majority of variables (for descriptive characteristics see table 1), however tennis players did display a significantly lower (*P* < 0.05) BMI, muscle mass and knee flexion strength than non-players. When *t*-tests were performed separately for males and females (data presented in Table 1), as non-players had slightly more male participants, no differences were reported between female subjects. On the contrary, males in the tennis playing group still displayed significantly lower BMI and muscle mass but no difference in knee flexion.

Table 2 displays the physical activity data collected from the IPAQ of both groups. Although crucially no significant difference was reported in total physical activity, vigorous intensity exercise, sitting time or walking time, tennis players did report a significantly greater (*P* < 0.05) amount of time taking part in moderate intensity exercise than non-players.

Table 3 illustrates MDF slope (%.min-1) of each agonistic muscle during handgrip, knee extension and knee flexion fatiguing protocols. All participants completed fatigue measurements, however some data were excluded from the final analysis due to poor signal or equipment error. For clarity, a more negative MDF slope indicates a greater level of fatigue in that muscle. When group means were compared by independent *t*-tests, no significant differences in fatigue were detected for any of the studied muscles (*P* > 0.05).

*Cluster analysis*

For analysis of overall MSK function, clusters were created from markers of adiposity, strength and physical performance data. More specifically, standardised z-scores of these 3 key categories were summed to provide measures of both upper and lower body function. Firstly, to assess the upper extremity, body fat percentage was combined with handgrip strength and flexor carpi radialis fatigue, to create cluster 1 (C1). When compared by ANCOVA (using age as a covariate) tennis players revealed a significantly greater score in C1 than non-players (tennis players = 0.33 ± 1.93 (n=42) vs. non-players = -0.26 ± 1.66 (n=47), *P* < 0.05). Secondly, to compare lower body function and to create cluster 2 (C2) z-scores of body fat percentage, knee extensor strength and rectus femoris fatigue were combined. Once again tennis players demonstrated significantly greater function than non-players in this cluster (tennis players = 0.17 ± 1.76 (n=40) vs. non-players = -0.16 ± 1.70 (n=46), *P* < 0.05). Lastly, to assess the lower body further and formulate cluster 3 (C3), standardised scores of body fat, knee flexion and biceps femoris fatigue were summed and compared by ANCOVA, although no differences was observed between groups in this final cluster (tennis players = -0.29 ± 1.69 vs. non-players = 0.24 ± 1.88, *P* > 0.05). Figure 1 highlights the significantly greater overall MSK function of both upper and lower body clusters (C1 and C2) in tennis players vs. non-players.

**Discussion**

Although the health benefits of tennis have previously been documented 24,30, this is the first study to employ cluster analysis in an attempt to elucidate its potential to enhance MSK health. Moreover, with the presence of a healthy active control group, these benefits can be attributed to tennis specifically, independent from those normally associated with increased physical activity. Past literature has also clearly identified tennis as a sport which promotes longevity, epidemiological studies in particular have highlighted a much lower mortality rate in those whom regularly partake in the game 27,28. Smaller studies have suggested tennis players possess more favourable body composition components than non-players 22,35. Additionally, several researchers have demonstrated that tennis players have an enhanced grip strength in the dominant arm. However, only Laforest et al. 22 were able to demonstrate a significant difference in knee extensor strength. It is plausible that conflicting results of past studies is due, at least in part, to the previous studies not fully accounting for the impact of varying activity levels. In the current study, having taken into account gender effects, no significant differences in strength were reported and only a slightly more favourable BMI was seen in male tennis players. Nevertheless, following cluster analysis a significant difference was reported, likely owing to marginal differences in each measure contributing to a greater collective effect on overall MSK function. Importantly, this finding not only expands upon the work of other authors in demonstrating the superior physical condition of tennis players but more specifically highlights its potential in a previously understudied area, where newer, more practical alternatives to existing physical activity recommendations are much needed.

As discussed above, there is some convincing evidence in favour of tennis’s ability to enhance and maintain MSK health. Presently, there is a distinct lack of research investigating fatigability in tennis and how it compares to other sports/activities. To date, some support has been found, documenting a greater resistance to fatigue in tennis players during sustained isometric knee extension, when compared to active non-players 22,37. Indeed in the current study, when both measures of muscular fatigue during handgrip and knee extension were combined with markers of adiposity and upper and lower body strength respectively, tennis players displayed enhanced overall condition. To put the findings into context, decreases in both isometric strength and EMG activity have been shown to be more pronounced in older adults 1. Consequently, when tennis player’s greater resistance to fatigue is coupled with greater isometric strength and reduced body fat percentage, their functional capacity is enhanced and the normally associated decline with age is much reduced. Moreover, this is the first time that EMG fatigability has been employed as a measure of physical performance in a cluster of overall MSK health. Although based on existing guidelines in the field established by Cawthon et al. 7, which specify walking speed and chair stand tests, this variation offers a more sensitive measure of physical performance. Although not always practical this does highlight the need for more accurate and reliable alternatives for populations, where traditional markers may not be sensitive enough to detect differences in MSK function, such as younger or middle aged adults.

While this study contributes to the growing body of evidence detailing the many positive benefits of regular tennis participation, it is not yet clear, why tennis is so uniquely effective at enhancing musculoskeletal health. Repeated bouts of high intensity aerobic exercise have previously been shown to be particularly successful at promoting neuromuscular function 4. Additionally, resistance training has also been associated with improvements in resistance to muscular fatigue 34. Evidently, this would suggest that concurrent training, as outlined by the current American College of Sports Medicine (ACSM) guidelines 15, combining both modalities would lead to the optimal conditions for enhanced MSK health. Nevertheless, in this study many of the non-players were routinely following these guidelines but still had markedly lower MSK functionality than the tennis players, evidenced by lower cluster scores in both the upper and lower extremity (see figure 1). A possible explanation is that tennis not only replicates the benefits of both aerobic and resistance exercise through its natural game play but it also tends to be played for much longer periods than many other sports 21. Notably, despite no difference in overall physical activity and vigorous intensity exercise in the present study, tennis players tended to spend more time exercising at moderate intensities than non-players, likely leading to a greater relative workload and consequently, a greater physiological response. Most tennis matches will last in excess of one hour, with short bouts of high intensity exercise (4-10 seconds) and minimal rest periods (10-20 seconds); typically completing 300-500 intensity efforts a match 14. These numerous bursts of high intensity exercise bring about moderate physiological responses, equating to approximate intensities of 60-80% maximal heart rate, 60-70% maximal oxygen consumption and blood lactate values in the region of 2-4 mmol.L-1 31,36. In combination with minimal rest periods, this work to rest ratio means tennis players continuously exhaust the phosphocreatine system and rely heavily on glycogenolysis and glycolysis to sustain efforts, resulting in increased lactate levels, reduced pH and a considerable metabolic challenge to the exercising muscle 20. Moreover, it is also possible shifts in muscle activation patterns caused by a speed-accuracy trade-off during strenuous tennis play, may contribute to greater neuromuscular adaptations 32. Subsequently, the aforementioned stimuli promote alterations in both type 1 and 2 muscle fibres, leading to a phenotype with characteristics comparable to both shorter and longer duration sports 26 and thus, an all-round athleticism that translates to enhanced physical functioning across broad domains. Furthermore, players do not need to be of a certain calibre to reap these benefits, as demonstrated by Fernandez-Fernandez et al. 13 who reported no significant differences in any physiological responses or activity profiles of advanced and recreational veteran players. Ultimately, if played regularly, the ACSM’s target of recommended physical activity is readily achieved and likely surpassed, resulting in an improved MSK profile.

Nonetheless, this study is not without limitations, as a cross-sectional design has been employed it is only possible to assume that the differences between groups are caused by participants chosen physical activity and not another underlying factor. In order to account for this, an effort has been made to control for potential extraneous variables, such as age, gender, and physical activity level. However, socioeconomic data was not collected and may therefore still have a confounding effect. A more longitudinal design, such as a prospective cohort study or clinical trial, may be able to better account for these extraneous variables and is therefore required. Finally, although the non-players in this study were all considered active and at least meeting the government guidelines for physical activity, no information was collected regarding their chosen mode of physical activity. Future studies should provide more information in this regard, to provide further insight into how tennis may compare to other more specific modes of exercise.

In conclusion, the present study offers support for improved MSK functionality and adds to the existing tennis benefits literature base. Cluster analysis of body composition, muscular strength and fatigue data revealed significantly greater function in both the upper and lower extremities of tennis players compared to non-players. This may be due to the hybrid high intensity interval training nature of tennis. Tennis is not only an excellent activity mode to promote MSK health and aerobic fitness, it also provides a fun game-sport atmosphere. As such, tennis should be recommended more frequently as a viable physical activity for health and fitness.

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**Figure Captions**

Figure 1. Upper and lower body musculoskeletal function cluster scores of tennis players (TP) and non-players (NP). Cluster (C1) represents the upper body and is the sum of z-scores for body fat percentage, handgrip strength and flexor carpi radialis fatigue index. Cluster 2 (C2) represents the lower body and is the sum of z-scores for body fat percentage, knee extension strength and rectus femoris fatigue index. Data are means ± SEM. \*indicates a significant difference between tennis players and non-players when analysed by ANCOVA (age as covariate).

**Tables**

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| Table 1. Descriptive characteristics of tennis players (TP) and non-players (NP) for whole group and split by gender. |
|  | Mixed Gender | Males | Females |
|  | TP (n=43) | NP (n=47) | TP (n=18) | NP (n=26) | TP (n=25) | NP (n=21) |
| Age (y) | 44.35 ± 16.83 | 39.02 ± 16.95 | 47.50 ± 16.25 | 37.04 ± 17.49 | 42.08 ± 17.20 | 41.48 ± 16.35 |
| Height (m) | 1.69 ± 0.08 | 1.69 ± 0.09 | 1.74 ± 0.07 | 1.74 ± 0.08 | 1.66 ± 0.06 | 1.63 ± 0.07 |
| Weight (kg) | 68.23 ± 8.01 | 72.36 ± 11.39 | 70.22 ± 8.11 | 76.08 ± 9.68 | 66.80 ± 7.78 | 67.76 ± 11.89 |
| BMI (kg/m2) | 23.83 ± 2.80 | 25.19 ± 3.50\* | 23.08 ± 2.35 | 25.08 ± 3.14\*\* | 24.37 ± 3.02 | 25.34 ± 3.97 |
| Waist:Hip Ratio | 0.82 ± 0.07 | 0.84 ± 0.07 | 0.86 ± 0.06 | 0.87 ± 0.06 | 0.79 ± 0.06 | 0.78 ± 0.05 |
| Fat Mass (%) | 23.43 ± 7.63 | 23.16 ± 8.20 | 16.87 ± 5.22 | 18.32 ± 7.04 | 28.17 ± 5.17 | 29.16 ± 4.93 |
| Fat Mass (kg) | 15.89 ± 5.49 | 16.81 ± 6.67 | 11.95 ± 4.09 | 14.24 ± 6.56 | 18.73 ± 4.56 | 19.98 ± 5.42 |
| Fat Free Mass (kg) | 51.90 ± 8.11 | 55.56 ± 10.28 | 58.27 ± 6.72 | 61.84 ± 7.32 | 47.31 ± 5.56 | 47.78 ± 7.82 |
| Muscle Mass (kg) | 26.24 ± 3.57 | 28.10 ± 5.19\* | 28.58 ± 3.46 | 31.44 ± 4.03\*\* | 24.56 ± 2.60 | 23.97 ± 3.06 |
| Handgrip Strength (kg) | 33.51 ± 9.60 | 33.49 ± 9.67 | 41.39 ± 9.10 | 39.40 ± 8.13 | 27.84 ± 4.73 | 26.19 ± 5.58 |
| Knee Extension Strength (N) | 314.42 ± 113.36 | 363.23 ± 123.96 | 379.10 ± 130.51 | 439.72 ± 105.93 | 267.85 ± 70.90 | 268.53 ± 65.50 |
| Knee Flexion Strength (N) | 159.71 ± 55.14 | 188.3 ± 65.83\* | 196.77 ± 57.36 | 228.37 ± 58.01 | 133.02 ± 34.91 | 138.69 ± 33.04 |
| VO2MAX (ml/min/kg) | 39.20 ± 10.35 | 41.54 ± 10.22 | 44.60 ± 10.18 | 46.67 ± 9.85 | 35.15 ± 8.64 | 35.39 ± 6.76 |
| Data are means ± SD. \* indicates significant difference (*P* < 0.05) between tennis players and non-players when compared by independent *t*-test. \*\* indicates significant difference (*P* < 0.05) between tennis players and non-players when compared by independent *t*-test within respective gender. |

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| Table 2. International Physical Activity Questionnaire – Short Form (IPAQ-SF) responses of tennis players (TP) and non-players (NP).  |
|  | TP (n=25) | NP (n=27) |
| Vigorous Intensity (MET-min/week) | 1217.60 ± 1571.16 | 1408.89 ± 945.49 |
| Moderate Intensity (MET-min/week) | 1118.40 ± 851.15 | 494.81 ± 494.51\* |
| Walking (MET-min/week) | 861.96 ± 783.61 | 927.06 ± 656.05 |
| Total (MET-min/week) | 3197.96 ± 1975.69 | 2830.76 ± 1339.66 |
| Sitting (min/day) | 351.60 ± 156.25 | 447.78 ± 190.63 |
| Data are means ± SD. \*indicates significant difference (*P* < 0.05) between groups when compared by independent *t*-test. |

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| Table 3. Fatigue index of tennis players (TP) and non-players (NP), indicated by median frequency (MDF) slope (%.min-1) of the studied agonistic muscles during handgrip, knee extension and knee flexion.  |
| Muscles | MDF slope (%.min-1) |
| TP | NP |
| Handgrip |  |  |
| FCR | -1.79 ± 1.34 (n=42) | -2.48 ± 0.88 (n=47) |
| Knee extension |  |  |
| RF | -4.91 ± 1.49 (n=40) | -7.76 ± 0.97 (n=46) |
| Knee flexion |  |   |
| BF | -5.52 ± 2.02 (n=41) | -2.75 ± 1.83 (n=46) |
| Data are means ± SEM. Abbreviations: flexor carpi radialis (FCR), rectus femoris (RF) and biceps femoris (BF). |