Effect of exhaustion on dynamic balance of professional padel players

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Abstract
Padel is an intermittent multidirectional racket sport that uses tennis’ rules and its scoring system. The popularity of padel has seen exponential growth; becoming one of the most practiced sports in the world. Balance constitutes a central component of racquet sports competitive demands. The aim of this study was exploring the effect of an exhaustive exercise on dynamic balance in elite padel players. 34 first division padel players with national rankings (age: 31.6 ± 7.9 years, height: 181.1 cm ± 5.26 cm; body mass: 81.1 kg ± 9.95 kg) volunteered for this study. Subjects were first tested for dynamic balance using the Y balance test. Then, they performed a volitional exhaustion test, followed by a dynamic balance retest. A significant main effect of condition for all balance variables was detected (all \( p < 0.03 \)) except for the posterolateral distance. A significant main effect of time was only found for the anterior distance (\( p < 0.001 \)). Significant condition*time interaction was found for all variables (\( p < 0.02 \)) except for the posterolateral distance. Posthoc analysis of the condition × time interaction indicated that compared to the control condition, exhaustive exercise deteriorated balance as showed by the significant decrease in the composite score (\( p = 0.05 \)) and in the anterior direction (\( p < 0.001 \)). This makes us focus on elaborating novel training systems in padel to improve the anterior direction distance after fatigue, being the reason of the decrease of dynamic balance capacity. This will boost the possibilities of scoring during a competitive situation.

Keywords Racket sports · Fatigue · Equilibrium · Sport performance · Physical activity

Introduction

Over the last few years, the popularity of padel has seen exponential growth; becoming one of the most practiced sports in South America and Spain and expanding rapidly in more than 60 countries around the world [1]. The number of adherents in both amateur and professional levels has significantly increased, probably causing the decrease of the number of tennis adherents in some countries such as Spain, Portugal, and France [2]. In addition, the number of clubs in Spain and France has respectively increased during the last years: from 121 to 788 (between 2001 and 2013) and from 15 to 172 (between 2009 and 2017) [2].

Padel is an intermittent double racquet sport based on tennis rules and sharing with it some similarities in the scoring system. However, in contrast to tennis, padel is played inside an enclosed synthetic glass and metal court (10 × 20 m), allowing the use of side and back walls during the play to bounce the ball as support for easier and more inspiring gameplay [3]. Despite its gain of popularity, the scientific literature of padel’s specific performance requirements in its different sides (tactical, physical, …) and game dynamics is
still very limited [2, 4–6]. As a racquet sport, sharing many of the rules of tennis and squash and adopting a similar scoring system, padel fitness requirements would be expected to be very close to these sports [7]. Previous research has identified agility, short-distance sprints, strength, endurance, and balance as main determinants of performance in tennis players [8]. These determinants do not only serve to program and track training but also to identify risk factors for injuries [9]. In this regard, balance was given a crucial role in many sports including tennis due to its preventive role in reducing injury risks [10, 11]. A study which was conducted on soccer players proved that dynamic body balance scores can be included in the medical examination to recognize soccer players who are more exposed than others to the risk of injury [12]. The analysis of physical performance is an important tool that improves the level of play as it allows to establish good strategies and to put in place specific training programs and necessary evaluation tests [13–15]. This analysis method was also used in padel just like in the other sports [16].

During physical activities like rackets sports, heat force and metabolites are generated when muscles contract. This alters the equilibrium in the internal environment and causes fatigue and exhaustion depending on the intensity of exercise [17]. By definition, exhaustion is the reduction of muscle force production during or after a physical exercise. Maximal force or power that can be produced by muscles is measured to investigate exhaustion [18]. The level of fatigue is depending on different factors such as the duration, severity, and the type of the exercised physical activity. As the severity and the duration of the exercise increase, it alters the overall performance in a negative way. This is due to the increase in the level of fatigue [19, 20]. Padel has no limit of time. However, the average time of a padel match (90 min) is enough to induct a high fatigue level and the increase of the heart rate of padel players [21, 22]. Fatigue seems to be one of the causes affecting the global performance of a professional padel player. It was observed that successive matches during a World Padel Tour competition, an international padel tournaments circuit for the players having the highest level in the world, affected the global performance of the players and their different physical qualities (e.g., reaction time, explosivity, balance) [23].

Just like tennis, padel is an intermittent multidirectional sport. Competitive demands in such sports imply to continuously perform challenging tasks such as sprints, changes of directions, turns, and jumps [24, 25]. In many of these tasks, balance itself is a central component [24]. Balance is one of the most important physical qualities in daily life and sportive activities. Besides, high-level athletes in different sports showed good results in the dynamic balance tests, proving that dynamic balance is one of the most important requirements of high performance in sports competitions [26]. Pathologic conditions, gender, age, strength, anthropometric body structure are all factors affecting the balance performance [27]. In addition to these factors, exhaustion is highly affecting the dynamic balance results. With increasing game duration and the high-frequency tasks that the players need to perform throughout the play, balance could be subject to defects. In young tennis players, Malliou and Beneka [10] have shown that balance is, indeed, subject to failure after a regular training session. Previous research in padel demonstrated that both elite and recreational players display defects in dynamic balance [25]. More specifically, these authors demonstrated that both elite and recreational players display deficits in the anterior direction in the star excursion balance test, causing the deterioration of the global score of dynamic balance. Surprisingly, elite players displayed poorer balance in posteromedial reach direction than recreational subjects [25]. These data suggest that padel training could cause some muscular imbalances increasing the risk of injuries. Through this paper, we direct our effort to bridge a gap in the literature of Padel’s specific performance requirements. To our knowledge, no study has investigated whether fatigue induced by an exhaustive exercise could affect the dynamic balance of padel players. The aim of this study is to explore the consequences of an exhaustive exercise on dynamic balance in elite padel players.

Materials and methods

Subjects

Our sample consists of 34 professional padel players who volunteered for this study. Subjects have practiced padel regularly from four to six sessions per week during the last 7 years. Before any testing, the players became aware of the nature and constraints of the experiment. They received a detailed and clear explanation of the experimental protocol and were asked to provide written informed consent to participate in this study. All athletes had no medical contraindications and showed a clear motivation to participate. Exclusion criteria were age and the level of practice: Subjects were accepted to participate if their age was between 18 and 40 years and if they were playing in the first division of the national league at the time of the investigation. These data were checked with potential participants prior to getting their consent.

Experimental protocol

In a crossover design, subjects were randomized to two conditions and groups: an ex-balance group and a control group. The two conditions were preceded by informing the subjects about the experimental protocol and familiarizing...
them with the procedures of the tests. This visit served also to collect anthropometric data. Standing height and body weight were measured at the beginning of the familiarization session. Measurements were conducted by the same experimenter and with the same equipment: a 1-mm graduation tape measure (D03184 Duratool 5 M Tape Measure) and a 100 g precision electronic scale (WC-321 precision balance), and at the same time of the day.

We run a three-phase experiment over the participants. Subjects were first tested for dynamic balance using the Y balance test. Each subject was allowed three practice trials. They then performed a Bruce test to volitional exhaustion after which dynamic balance was retested again. Subjects also were allowed three practice trials, and these were included in the final analysis.

The control condition was identical to the ex-balance condition except that subjects have not performed a Bruce test before the retest. Subjects were rested on a chair for 20 min between the two dynamic balance testing procedures.

**Y balance test**

The FMS Professional Y-Balance Test Kit was used to perform the test. Subjects were required to stand on their dominant leg with the heel fixed on the center of the grid, while reaching as far as possible with the contralateral leg in three different directions (anterior, posteromedial, and posterolateral). Reach distance was measured from the most distal aspect of the toes of the stance to the most distal aspect of the reach foot in different directions. The best score of the three practice trials was considered for the statistical analysis whereas the three practice scores were considered for the reliability analysis.

A composite score was also calculated according to Negra et al. [28]:

\[
\text{Score} = \left( \frac{\text{maximum anterior distance}}{\text{leg length} \times 3} \right) \times 100. \\
\text{+ maximum posteromedial distance} \\
\text{+ maximum posterolateral distance}
\]

**Bruce treadmill graded exercise test**

To reach exhaustion, subjects performed a Bruce graded exercise test [15] starting from a speed of 2.7 km/h and a grade of 10. The speed and the grade were increased every 3 min until reaching volitional exhaustion. Subjects are supposed to perform on the treadmill for the longest possible duration and try to achieve their maximum predicted heart rate during this test. Expected heart rate max was calculated with this formula: 220-Age [18]. Besides, they can stop the test if some symptoms occurred such as acute fatigue, pain, shortness of breath, chest discomfort, or any other medical condition. However, at least 85% of their predicted maximum heart rate must be scored to be considered as a valid result.

**Blood lactate concentration**

To ensure the efficiency of the exhausting exercise, blood lactate concentration was measured two times: before the exercise and immediately after the test. A portable lactate analyser was used: Lactate Scout+ (LSP, SensLab GmbH, Germany). 0.5 μl of blood was collected via finger stick of the index finger of the athlete.

**Statistical analysis**

Data are presented as mean ± standard deviation (SD). Normality was checked using the Shapiro–Wilk test. A paired sample T-test was used to check any difference in baseline data across conditions. A two-way repeated measures ANOVA was used to analyze the effect of exhaustive exercise on dynamic balance across conditions. Bonferroni posthoc correction was used to detect differences whenever an interaction effect was found. Intra-class correlation coefficients were used to test the reliability of Y balance test data (only Data from the first visit were considered). The level of significant difference was set at \( p \leq 0.05 \).

**Results**

Subjects received each treatment condition as assigned. In total, 34 padel players with national rankings (age: 31.6 ± 7.9 years, height: 181.1 cm ± 5.26 cm; body mass: 81.1 kg ± 9.95 kg) completed the study, attained the two conditions and none reported any condition-related injuries. Heart rate and blood lactate concentration, which are considered as the fatigue indicators, increased in response to the volitional exhaustion inducted by the Bruce protocol test, showing that exhaustion was reached for all the athletes (Table 1).

| Score formula | \( \frac{\text{maximum anterior distance}}{\text{leg length} \times 3} \times 100 \) |

**Table 1** Levels of heart rate and blood lactate concentration before and after exercise

|                          | Pre test | Post test |
|--------------------------|----------|-----------|
| Heart rate (bpm)         | 57 ± 10  | 184 ± 9   |
| Lactate concentration (mmol L⁻¹) | 1.32±0.26 | 8.92±2.79 |
Statistical analysis revealed a significant main effect of condition for all balance variables (all \( p < 0.03 \)) except for the postero-lateral reach distance (Fig. 1). A significant main effect of time was only found for the anterior reach distance \( (p < 0.001; \) Fig. 1). Significant condition*time interactions were found for all variables \( (p < 0.02) \) except for the posterolateral distance. Posthoc analysis of the condition \( \times \) time interaction indicated that compared to the control condition, exhaustive exercise deteriorated balance as showed by the significant trivial decrease in the composite score \( (p = 0.05) \). Posthoc analysis of each individual reach direction distance revealed that compared to control condition, exhaustive exercise resulted in a significant decrease only in the anterior direction \( (p < 0.001; \) Fig. 1, Table 2).

**Discussion**

Our results suggest padel players usually struggle to get their balance quality maintained or improved after long-term physical activity. Their dynamic balance gets reduced mainly because of the decrease in the anterior direction distance reach. A high score in dynamic balance capacity is needed for a high level padel player. Balance, considered as one of the requirements of high performance, is affected by different factors including fatigue \([27, 29, 30]\). The heart rates of some of our athletes did not reach their predicted maximum heart rate. That is why the maximum heart rate mean of our participants did not achieve the expected maximum heart rate mean. However, these athletes stopped the Bruce protocol test just when they could not keep it anymore, which is the objective of our experiment. We can assume that this might be due to the differences in the physical conditions of the padel players as the expected maximum heart rate calculated is depending only on age \((220\text{-age})\), and not taking into consideration the rest of their physical qualities such as height, weight, fat mass, and so on. To confirm reaching exhaustion, blood lactate concentration was measured. All the players showed a huge increase of the blood lactate concentration after the exercise comparing to the pre-test values. High lactate concentrations can be the cause of fatigue by affecting the contraction process of the muscles and decreasing the execution capacity \([31]\).

The measured subjects performed similarly to some previous studies. In one of them, fatigue induced by fast walking had an impact on the control of balance \([32]\). In another study, the body error scoring system (BESS) was used before and after a 20-min fatigue protocol rated 15 on Borg Scale, in a population of male Division I college athletes. A higher error score was detected after fatigue, demonstrating that balance ability diminished \([33]\). Similarly, Ishizuka et al. \([34]\) found that balance decreased in the first 10 min after a high-intensity 20-min activity of football players.

In addition, exhausted individuals are at increased risk of injury because of balance loss. Avoidance of fatigue and preconditioning may prevent injury \([35]\) as the decrease of balance capacity can be the cause of different injuries during sports performance. Due to fatigue, injuries might happen especially after long-term sports activities. After fatigue,

**Table 2** Correlation coefficients for both control and ex-balance conditions of the \( Y \) balance

| Variables measures          | Control condition ICC | Ex-balance condition ICC |
|----------------------------|-----------------------|--------------------------|
| Composite score            | 0.96                  | 0.96                     |
| Anterior reach distance    | 0.89                  | 0.88                     |
| Posteromedial reach distance | 0.92                  | 0.91                     |
| Posterolateral reach distance | 0.98                | 0.98                     |

**Fig. 1** Results of the \( Y \) balance in the three different axes*.

*Numbers/columns appear as mean ± SD
greater postural sway may also be observed following long-term events such as biathlon, running, cycling, or after activities requiring specific technical skills, such as skiing [36]. In padel, the duration of a turning point varies, mainly, depending on age, sex, and level of the players obtaining longer durations at higher levels. In this case, the higher the level, the longer the duration of a turning point. The duration of the padel point and the match intensity might be the cause of exhaustion and clearly affect different variables of the game and the outcome of the match [37]. All the above-mentioned data are in line with the results of our study.

Padel players showed already a deficit in the dynamic balance capacity and the anterior direction distance in particular. It seems that as capacity gets even worse after exhaustion it might increase the risk of injuries after a long term padel exercise or competition. Padel is a multi-directional sport, which means that quick changes of direction (frontal, diagonal, lateral, turns) usually occur during the gameplay [38]. In this case, having a low score in dynamic balance would decrease the athlete’s stability and make the risk of injuries higher. Padel players are already showing low scores in dynamic balance and the anterior direction reach distance even without any physical exercise comparing to other athletes from different sports. This might be explained by the nature of the padel training systems which is based on unilaterality of the movements. This might be the cause of the lack of symmetry between both sides dominant and non-dominant [39]. Also, the fact that high level athletes showed lower dynamic balance scores in posteromedial reach direction than amateur players can cause lower body injuries such as pain, ankles injuries, and ligaments injuries. Another study associated the lack of balance and the reduced strength of ankle musculature with functional instability [40]. That is why, avoiding this risk has to be a primordial goal for the coaches and players through changing their training methods, which have to focus more on strengthening the lower limb power and performing more dynamic balance exercises during their training sessions. The muscles of the lower part of the body are mainly responsible for maintaining the overall balance. It was shown that localized fatigue at the knee and hip of both flexor and extensor muscles had a negative effect on balance and postural control in the frontal and sagittal planes [27].

This decrease in body balance was explained by the deficiency of the muscular system [41]. High-intensity activities to exhaustion influence kinaesthetic awareness and motor control [42]. According to Bizid et al. (2009), the decrease of the function of motor-neuron outputs of afferent muscles and their sensitivity was the main cause of the decreasing body balance [43]. Some other studies showed that fatigue had an effect on muscular effectors and sensory inputs provoking as a result a poor postural regulation. It is due to the fact that ankle joints were not able to catch the same angle anymore after reaching volitional exhaustion [44, 45]. This obviously shows the importance of high-intensity training for the adaptation of the central nervous system [46]. The objective is to maintain dynamic balance even while reaching exhaustion during physical activities. It was shown that the mechanisms of the central nervous system are responsible for the dynamic balance of ankle stability instead of the mechanisms of the peripheral reflexes [47]. Neural systems termed central effectors of the central nervous system are the main responsible structures of providing the needed response to ensure a positive energy balance. Besides, balance is disturbed when alterations in any of these inputs occur, thus increasing the risk of injury [48]. It was shown also that fatigue reduces motor drive by the inhibition of lower motor neurons at the spinal level [49], which is the cause of the reduction of the muscle fibers velocity. This leads to the decreases of the neuromuscular control and technically the dynamic postural control [50–52].

Conclusions

Research is lacking when it comes to the practice of padel and the different performance requirements related to it. Despite the drastic growth of the interest of players in Padel worldwide, the research provided for this matter still gives little insight into the effect of exhaustion on balance when it comes to padel players. We intend through this study to explore the effect of an exhaustive exercise on dynamic balance in professional padel players. We targeted professional players having a minimum of 7 years of experience from the age range of 18–40 years old. We conclude that A significant difference was detected in the anterior direction reach distance after fatigue, causing the deterioration of the global dynamic balance. This result sheds light on giving more attention to lower limb strengthening and implementing balance specific exercises in padel training sessions. The latter is crucial to reduce the negative effect of fatigue, decrease the risk of injuries, and improve technical effectiveness. Thus, these exercises would play a part in boosting the possibilities of scoring during competitive situations. Therefore, future work should be directed to exploring novel diagnostic systems and methods to analyze and evaluate the effect of exercise on balance and its adaptive changes due to systematic training in padel.

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Declarations

Conflict of interest The authors have no relevant financial or non-financial interests to disclose.

Ethical approval I hereby confirm that this work is the authors’ own original work, which has not been previously published anywhere else, and the paper is not currently being considered for publication elsewhere. All sources are shown as correct citations.

Informed consent Informed consent was obtained from all individual participants included in the study.

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