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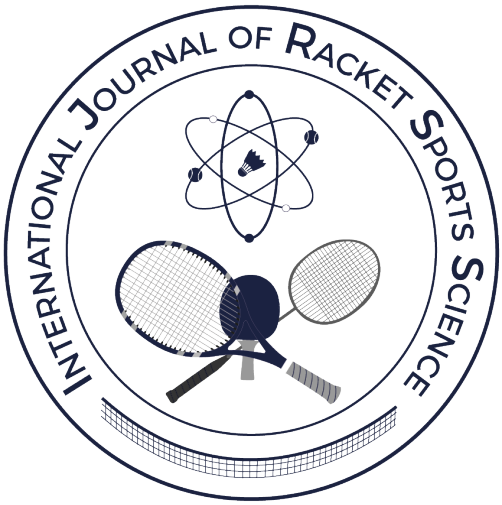

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Original Investigation

Does ischemic pre-conditioning during the recovery period between two successive matches preserve physical performance in badminton doubles players?

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Abstract

Changes in physical performance were assessed in response to two successive doubles badminton matches with implementation of ischemic pre-conditioning (IPC) or sham treatment during recovery period between matches. Eight French national team badminton players (4 males, 4 females) performed two successive doubles matches (2 × 45 min), with 60 min of recovery in-between, during which they received three 5-min cycles of either an IPC (220 mmHg) or a sham (SHAM) (50 mmHg) intervention. A series of physical tests was performed immediately following the first (Post 1) and second (Post 2) match. Jump height (squat and countermovement jumps), leg power (multi-rebound jumps) and sprint time (L-test) remained unchanged from Post 1 to Post 2 (all P>0.193), and did not differ between conditions (all P>0.173). During a badminton-specific repeated-agility test, neither performance-related variables (i.e., best time, total time and sprint decrement score) nor *vastus lateralis* muscle tissue saturation index displayed a main effect for condition (all P>0.116), time (all P>0.091) or time × condition interaction (all P>0.730). Implementing IPC during the recovery period between successive doubles badminton demonstrated no beneficial effect on physical performance and muscle oxygenation trends.

Keywords: *Blood flow restriction; Recovery strategy; Racket sports; On-court performance; Muscle oxygenation*

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INTRODUCTION

Badminton is a high-intensity, intermittent activity characterized by repeated movements involving starts, stops, jumps, leaps, lunges and rapid directional changes. It is recognized as the fastest racket sport in the world, and imposes high physiological and neuromuscular demands (Phomsoupha & Laffaye, 2015). Badminton tournaments have intense schedules and are fairly congested in nature, often requiring players to compete in 1-2 matches a day for a period of 2-4 consecutive days. The repetition of rapid and intense leg movements and a wide range of body postures likely result in profound lower limb fatigue (Phomsoupha & Laffaye, 2015). For instance, two successive 35 min badminton matches decreased maximal voluntary torque in both plantar flexors and extensors, with even larger decrements for explosive contractions (Girard, Behan, Cabello-Manrique, & Fernandez-Fernandez, 2019). Moreover, following fatiguing match-play, decreased control of the midfoot and increased arch collapse have been observed during lunge movements in both male and female players, resulting in increased injury risk during diagonal movement tasks (Valldecabres, Richards, & De Benito, 2020). As such, interventions that might enhance and/or preserve badminton-specific endurance and/or facilitate between-match recovery may be invaluable to maintain match competitiveness and minimize the risk of injury.

Ischemic pre-conditioning (IPC) is a technique which involves subjecting tissues to cycles of sub-lethal levels of ischemic stress followed by reperfusion. In clinical medicine, IPC has been shown to confer protective effects to various organs subsequently exposed to prolonged ischemic episodes (Stokfisz, Ledakowicz-Polak, Zagorski, & Zielinska, 2017). Within exercise science research, the use of IPC has emerged as an attractive ergogenic aid for athletes to improve exercise capacity. For instance, three to four intermittent cycles of brief (~5 min) arterial limb occlusions have been shown to improve maximal power output or time to exhaustion during incremental cycling tests (Cheung, Slysz, & Burr, 2019; De Groot, Thijssen, Sanchez, Ellenkamp, & Hopman, 2010), as well as running time-trial performance (Bailey et al., 2012). The effect of IPC on anaerobic-type performance is more controversial (Gibson, White, Neish, & Murray, 2013; Patterson, Bezodis, Glaister, & Pattison, 2015). For instance, no performance alterations for single (30 m) or repeated sprints (5 × 6 s) occurred following IPC (Gibson et al., 2013). However, in another study where repeated-sprint ability (RSA) sequences were prolonged (12 × 6 s), IPC significantly increased peak and mean power outputs for the initial portion of the sprint sequence (Patterson et al., 2015). Purported mechanisms underpinning the ergogenic effects of IPC include improved blood flow and oxidative metabolism (Incognito, Burr, & Millar, 2016). Indeed, improved muscle oxygenation profile has been shown to coincide with improved cycling RSA performance (Patterson et al., 2015) as well as repeated maximal knee extensor strength (Paradis-Deschênes, Joanisse, & Billaut, 2016).

Besides its acute effects on subsequent exercise capacity, there is emerging research investigating how IPC might accelerate the recovery of physical performance. Garcia, da Mota, Leicht, and Marocolo (2017) demonstrated that IPC does not improve recovery of jumps and agility performance acutely (within 1 h) within sub-elite rugby players following a rugby-specific exercise protocol. Conversely, beneficial effects on functional measures of athletic performance, including RSA and jump height, were observed 24 h after an IPC intervention (Beaven, Cook, Kilduff, Drawer, & Gill, 2012). There are, however, no reports currently detailing the influence of IPC on the recovery of badminton-specific physical performance (i.e., jumps, directional changes, repeated-agility test) and associated tissue oxygenation trends.

Therefore, the aim of this study was to investigate the effect of IPC on between-match recovery in physical performance, as well as associated changes in muscle oxidative profile during successive badminton matches.

METHODS

Participants

Eight players (4 males, 4 females; age 21.3 ± 2.7 years, body mass 70.0 ± 10.0 kg, height 177 ± 12 cm) from the French national badminton doubles team were recruited. Sample size estimation required n=10 players, assuming a power of 0.80, α level of 0.05 and expected change in performance to be small (i.e., effect size = 0.25). However, due to our stringent inclusion criteria (i.e., national level doubles players), player availability, injury and logistical constraints, only 8 players were assessed. One player withdrew from the second trial due to injury (finger) and therefore final data set is presented as n=7. The local committee waived the requirement for ethical approval for this study, given that all measurements were performed in the context of their national team's daily routine training monitoring (Winter & Maughan, 2009). Written informed consent was obtained from players prior to participation.

Experimental design

All measurements were conducted during the competitive season (November 2018) at the French Institute of Sport's badminton training facility (Paris, France). Players were tested on two separate occasions 2-3 days apart to minimize the effect of residual fatigue on the subsequent test results. After a 15 min warm-up, they played two simulated matches lasting 45 min each, with 60 min rest in-between (total of 150 min). The players were paired according to level of play (similar national rankings) and gender, and competed

against the same pair of opponents. The matches were played according to the Badminton World Federation rules, and a (minor) reward was offered to the winning player to ensure maximal "competitive" effort by all participants. The players were supplied with pure water at the sidelines with *ad libitum* intake during the matches. Following (i.e., 3-5 min) the first match (Post 1), players performed a series of performance tests including vertical jumps [squat jumps (SJ), countermovement jumps (CMJ) and multi-rebound jumps (MRJ)], the 'L' agility sprint test (L-test), and lastly a badminton-specific repeated-agility test. Thereafter, they received three 5-min cycles of either IPC or SHAM (single-blind, crossover design) administered in a bilateral manner (i.e., alternating between thighs every 5 min during 30 min), whilst in a seated position. The time delay between the end of the first match and the commencement of IPC procedure was exactly 15 min. Players then proceeded with a 5 min badminton re-warm-up before playing the second 45 min match, following which, the performance tests were repeated again (Post 2). All trials were performed at the same time of day to avoid potentially confounding circadian rhythm effects. Players were asked to perform tests with their usual competition court shoes. All players were familiar with the testing protocols and procedures, which are part of their regular serial physical fitness assessments. Care was taken to advise the players to avoid high-intensity and strenuous training within 24 h of their scheduled test.

Ischemic preconditioning

Immediately after the performance tests following the first match, players were administered three 5-min cycles of either IPC or SHAM in each thigh whilst in a seated position, alternating thighs, totaling 30 min. A 13.5 cm wide cuff, connected to an automated rapid cuff inflator (Hokanson, Washington, USA) was positioned bilaterally on the most proximal regions of the thighs. The occlusion pressure was held constant at 220 mmHg and 50 mmHg for IPC and SHAM conditions, respectively. This light level of inflation (50 mmHg) has been shown to elicit the sensation of pressure around the thigh without preventing blood flow (De Groot et al., 2010). To minimize any placebo effect, players were told that the purpose of the study was to compare the impact of two different cuff pressures that could both alter performance.

Performance tests

Vertical jumps

Players performed the following jump tests twice starting with the SJ, followed by the CMJ and MRJ. All jumps were recorded (flight times for SJ, CMJ and MRJ and ground contact for MRJ) using a sensor system (Optojump Next, Microgate, Bolzano, Italy). Jump height for the SJ and CMJ tests was determined from flight times (Lehance, Croisier, & Bury, 2005). Leg power ($W.kg^{-1}$) during the MRJ test was calculated, as described elsewhere (Dalleau, Belli, Viale, Lacour, & Bourdin, 2004). The coefficient of variation (CV) for jump height during SJ and CMJ using the Optojump system is 3.1 % and 2.2 %, respectively (Glatthorn et al., 2011).

'L' agility test

The L-test was adapted from previous work (Gabbett, 2006). Three markers were positioned 5 m apart in the shape of an 'L', with electronic timing gates (Polifemo, Microgate, Italy) placed 1 m above the ground level and positioned at the start/finish line of the course. The players assumed position just before the start line, and once ready, ran forward for 5 m, before making a 90° turn to their left, after which ran a further 5 m before making a 180° turn to resume the same course back to the start/finish line. Two trials interspersed by 1 min of rest were performed, with the fastest time achieved included for analysis. The CV for this test is 1.96 % (Stewart, Turner, & Miller, 2014).

Badminton-specific repeated-agility test

Players performed six agility efforts with 20 s of recovery in-between, in a pre-determined sequence along the four corners of the court. The start/finish line was positioned at the mid-point of the baseline, whilst the service (i.e., forecourt) and baseline (i.e., rear court) corners of the court were affixed with markers. A 10 × 10 cm square was marked at the mid-point between the service and baseline (i.e., center), and electronic timing gates (Polifemo, Microgate, Italy) were positioned at the start/finish line. Each sprint involved the following running sequence: start/finish, center, right forecourt, center, left forecourt, center, left rear court, center, right rear court, center, start/finish line. Three scores were calculated during the test: the best sprint time, the total sprint time and the percent sprint decrement (S_{dec}) [{(total sprint time)/(best sprint time×6)−1×100]. Players were reminded to adhere to badminton-specific movements, start by moving towards the direction of their dominant hand (racket-holding hand), and to strike the up-turned shuttlecock also with their dominant hand. The CVs for mean sprint times for a similar badminton-specific agility test ranged from 3.9 % to 5.2 % in elite to skilled players (Phomsoupha, Berger, & Laffaye, 2018).

Physiological and perceptual measurements

Blood lactate

Capillary blood samples were taken from the players' fingertip prior to commencing the first match, as well immediately following the cessation of the first and second match. All samples were immediately analyzed for blood lactate concentration via a handheld analyzer (Lactate Pro 2, Arkray Inc, Japan).

Perceptual ratings

Rating of perceived exertion (RPE) and perceived fatigue were recorded following the first and second match using a 10-point scale. Zero was anchored as the positive (i.e., no exertion/fatigue, respectively), and 10 (i.e., maximal exertion/fatigue, respectively) the negative end of the continuum.

Near-infrared spectroscopy

Muscle oxygenation of the *vastus lateralis* was monitored using a wireless NIRS system weighing 75 g with approximate dimensions (i.e., W x D x H) of 84 x 43 x 17 mm. (Portamon, Artinis Medical Systems, The Netherlands). The Portamon simultaneously uses the modified Beer-Lambert and spatially-resolved spectroscopy methods to determine changes in oxygenated haemoglobin and de-oxygenated haemoglobin, expressed in micromolar units (μM). This system also provides a measure of oxyhaemoglobin saturation indicated by the tissue saturation index [TSI (%)], which reflects the dynamic balance between O_2 demand and supply within the muscle microcirculation (Ihsan, Abbiss, Lipski, Buchheit, & Watson, 2013). The Portamon unit consists of three emitter diodes positioned 30, 35, and 40 mm from the detector, and emitting infrared light at wavelengths of 760 and 850 nm. All analyses were undertaken on data gathered from the 35 mm emitter-detector distance, corresponding to a NIRS signal penetration depth of approximately 17.5 mm (McCully & Hamaoka, 2000). The Portamon unit was secured on the players' 'lunge' limb, using adhesive tape reinforced with elasticated bandages to prevent movement and signal contamination from external light sources. The probe site was marked for accurate re-positioning. Prior to test commencement, players unweighted their 'lunge' leg, and stood for a 30 s period during which baseline TSI was obtained. Muscle de-oxygenation during the repeated-agility test were characterized by obtaining the mean (CV = 4.6 %), minimum and area under the curve (AUC) of TSI signals during work-intervals (Ihsan et al., 2013). Finally, we calculated the i-TSI index as follows: iTSI = ($TSI_{Baseline}$ – TSI_{Mean}) × exercise duration. All analysis and interpretation were undertaken using the TSI, given that this variable has been suggested to provide a better indication of muscle oxygenation status when blood flow is not constant (Wolf, Ferrari, & Quaresima, 2007).

Statistical Analysis

Two-way repeated measures ANOVAs [Time (Post 1 and Post 2) × Condition (IPC and SHAM)] were used to compare data followed by *Bonferroni* post-hoc analysis procedure adjusted for multiple comparisons. For each ANOVA, partial eta-squared (η_p^2) were calculated as measures of effect size. Values of 0.01, 0.06, and above 0.14 were considered as small, medium, and large, respectively. All statistical calculations were performed using SPSS statistical software V.24.0 (IBM Corp., Armonk, NY, USA). The significance level was set at $P<0.05$.

RESULTS

Compared to the first match, RPE was significantly elevated ($P=0.050$, $\eta_p^2=0.48$) during the second match, independently of conditions ($P=0.689$, $\eta_p^2=0.03$) (Table 1). Badminton did not induce any change in blood lactate concentrations between matches ($P=0.972$, $\eta_p^2=0.05$), nor resulted in any difference in blood lactate concentrations between conditions ($P=0.833$, $\eta_p^2=0.01$).

Physical performance indices are presented in Figure 1 and Table 2. There was no main effect of time (all $P>0.272$, $\eta_p^2 > 0.20$), condition (all $P>0.173$, $\eta_p^2 > 0.28$) or time × condition interaction (all $P>0.379$, $\eta_p^2 > 0.13$) for jump height during SJ and CMJ tests, as well as for leg power during the MRJ test (Table 2). Sprint time during the L-test remained unchanged from Post 1 to Post 2 ($P=0.193$, $\eta_p^2 = 0.26$), and did not differ between conditions ($P=0.362$, $\eta_p^2 = 0.14$) (Table 2).

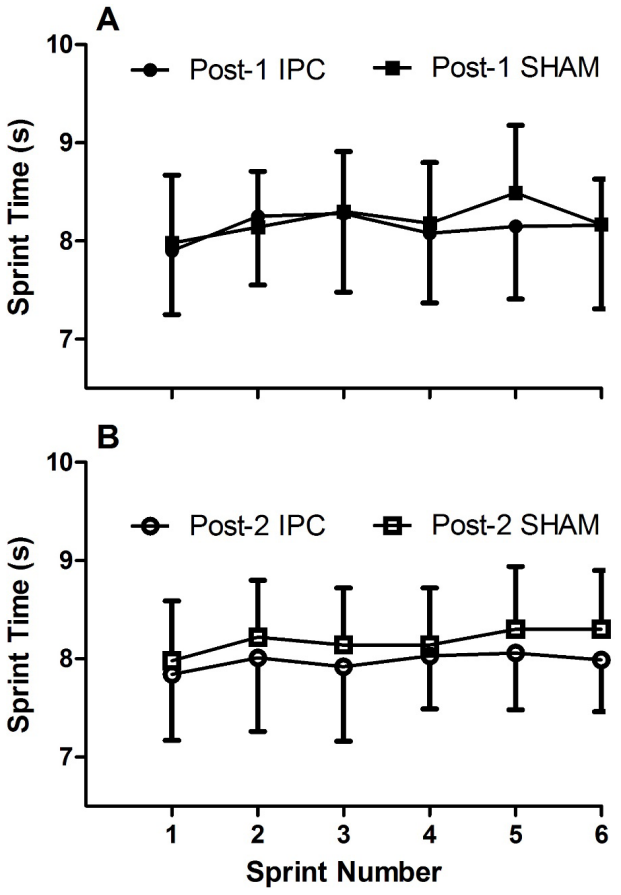

Figure 1. Changes in 'L-test' sprint time from the first (Post 1, *panel A*) to the second (Post 2, *panel B*) 45-min badminton match with ischemic preconditioning (IPC) or sham (SHAM) interventions implemented between matches.

Table 1.
Match characteristics for the first (post-1) and the second (post-2) 45-min badminton match with ischemic preconditioning (IPC) or sham (SHAM) interventions implemented between matches.

	IPC			SHAM		
	Pre	Post-1	Post-2	Pre	Post-1	Post-2
HR (bpm)	98 ± 22	130 ± 15	138 ± 23	100 ± 21	144 ± 23	153 ± 19
Blood lactate (mmol.L^{-1})	1.4 ± 0.7	1.6 ± 0.7	1.4 ± 0.6	1.6 ± 0.7	1.5 ± 0.9	1.6 ± 0.9
RPE (0-10)	-	4.1 ± 1.8	5.9 ± 1.8*	-	3.7 ± 0.8	5.1 ± 1.2*
ROF (0-10)	-	5.5 ± 2.6	6.7 ± 1.7	-	4.5 ± 1.8	5.9 ± 1.8

Data are mean ± SD. HR, heart rate; RPE, ratings of perceived exertion; ROF, ratings of fatigue.
** different from Post-1 (P<0.05).*

Table 2.
Vertical jump ability, L-test and repeated-agility test performance after the first (post-1) and the second (post-2) 45-min badminton match with ischemic preconditioning (IPC) or sham (SHAM) interventions implemented between matches.

	IPC		SHAM	
	Post-1	Post-2	Post-1	Post-2
Vertical jump ability				
SJ (cm)	38.9 ± 8.2	39.5 ± 7.5	38.4 ± 7.5	38.4 ± 7.9
CMJ (cm)	41.1 ± 8.0	40.7 ± 7.7	39.9 ± 7.8	40.1 ± 7.5
MRJ (cm)	36.0 ± 6.2	34.7 ± 7.5	36.5 ± 7.3	35.9 ± 6.5
Leg power (W.kg^{-1})	49.4 ± 7.4	48.1 ± 8.4	49.6 ± 8.4	48.5 ± 7.0
L-test				
Time (s)	5.18 ± 0.29	5.17 ± 0.38	5.16 ± 0.35	5.09 ± 0.33
Repeated-agility test				
Best time (s)	7.83 ± 0.72	7.90 ± 0.63	7.85 ± 0.68	7.93 ± 0.62
Total time (s)	48.82 ± 4.23	48.51 ± 3.86	48.91 ± 3.71	48.92 ± 3.68
S_{dec} (%)	3.97 ± 2.48	2.28 ± 0.86	4.02 ± 3.31	2.84 ± 2.00
Post-exercise RPE (6-20)	16.0 ± 1.7	16.8 ± 2.2	15.8 ± 1.2	16.4 ± 2.1

Data are mean ± SD. SJ, squat jump; CMJ, countermovement jump; MRJ, multirebound jump; S_{dec}, sprint decrement score; RPE, ratings of perceived exertion.

During the repeated-agility test, none of the RSA-related variables displayed a main effect of time (all P>0.091, η_p^2>0.40), condition (all P>0.600, η_p^2>0.05) or any significant time × condition interaction (all P>0.730, η_p^2>0.10) (Table 2). RPE tended to be elevated in response to the repeated-agility test performed post-2 *versus* post-1 (P=0.076, η_p^2=0.44). Sprints 1-6 averaged TSI-min (P=0.031, η_p^2=0.57), TSI-mean (P=0.042, η_p^2=0.52) and TSI-AUC (P=0.089, η_p^2=0.41) values were lower during the repeated-agility test performed Post 1 *versus* Post 2, irrespectively of condition (all P>0.466, η_p^2>0.10) (Table 3). Changes in i-TSI between Post 1 and Post 2 were not significant (P=0.116, η_p^2=0.36), with also no effect of condition (P=0.951, η_p^2=0.01).

DISCUSSION

Success in a badminton tournament requires winning consecutive matches on the same day sometimes separated by less than 1-2 h. Recovery strategies are therefore crucial to sustain optimal on-court performance during matches repetitions, as well as to preserve the health and wellness of the player. In this regard, we asked the original question whether IPC can promote the recovery in physical performance when administered in-between consecutive bouts of badminton match-play. Implementing IPC during the recovery period between successive badminton double matches had no significant effect on the recovery of physical performance in doubles badminton played by elite players.

One common measure to reflect explosive power is vertical jump ability. This fitness component is crucial in badminton, as it results in the player being able to move quickly and explosively to the shuttle in various directions and to jump high to execute overhead strokes. In our study, vertical jump ability (SJ and CMJ heights or leg power, all in the vertical plane) changes were not significant from successive matches with or without IPC application. Our mixed-gender cohort could at least partially account for the lack of an ergogenic effect, as IPC seemed to enhance muscle force production in males but not in females (Paradis-Deschênes, Joanisse, & Billaut, 2017). Alternatively, it can be postulated that IPC was ineffective due to the prior lack of performance decrement demonstrated

following match-play. Indeed, physical performances were not appreciably altered by successive badminton matches, indicating that the ability of the lower extremity to produce explosive force was probably not significantly impaired in our double players. Here, with simulated matches undertaken competitively, we observed comparable SJ and CMJ, as well as HR and RPE values to previous studies documenting the physical profiles (Ooi et al., 2009) and match-play characteristics (Liddle, Murphy, & Bleakley, 1996) of elite singles and doubles badminton players. Unfortunately, further comparisons are limited, as to the best of our knowledge no previous studies examining muscle fatigue following either simulated or actual doubles match-play. It is hence pertinent to address whether fatigue is a limiting factor in elite doubles match-play, at least with regards to two successive matches. Findings from singles match-play supports this notion, as Abián-Vicén, Del Coso, González-Millán, Salinero, and Abián (2012) reported no decrements in jump height (which actually increased by 4.5%) and mean power in the push-off phase of CMJ in their analysis of 70 singles matches played during the national Spanish championships. However, there is now emerging evidence showing that in elite players, muscle fatigue may be evident through subtle measures such as loading characteristics, rather than changes in force or power (Herbaut & Delannoy, 2020; Valldecabres et al., 2020). As such, future studies examining the effects of match-play fatigue or recovery interventions should extend their measurement tools to include players' movement re-organisation or compensatory mechanisms.

Previously, it was also observed that IPC of the thigh muscles did not improve the short-term recovery of performance or perceived recovery status for amateur rugby players following a simulated match (Garcia et al., 2017). Moreover, the current findings demonstrate no beneficial effects of IPC treatment during the recovery between successive games on player's ability to jump. Accordingly, well preserved leg power values (as derived from MRJ jumps) from successive matches with IPC application would indicate that this intervention probably had no effect on acceleration and speed when lifting off the floor when moving or jumping to the shuttle. However, horizontal power is also an important quality in taking lunge jumps to net shots (Phomsoupha & Laffaye, 2015). Hence, a greater horizontal power would result in the player being able to reach the shuttle more quickly, and thus force a faster pace of play. Future studies should determine whether successive matches and/or an IPC intervention likely modify this aspect of the match.

On-court movements are influenced by players' ability to accelerate, decelerate and change direction, in order to generate optimal stroke production. Whereas vertical jump ability (SJ and CMJ heights or leg power, all in the vertical plane) changes were not significant, it cannot be ruled out that a less efficient ground force application may then decrease the change of direction performances, as indirectly evaluated here from L-test. Unchanged performance during the L-test would suggest that the ability to move to and from the shuttle was probably not modified as a result of fatigue and/or application of the IPC treatment. A previous study showed that a 45 min simulated singles badminton match produced moderate-to-high levels of indirect markers of muscle damage (e.g., myoglobin, CK, and LDH), yet it was not associated with decreased agility T-test performance (Abián et al., 2016). We did not measure the extent of muscle damage in our cohort of double players. A possible explanation is that the neuromuscular demand (intensity of change of direction movements) associated with doubles badminton is typically less intense than singles (Alcock & Cable, 2009). Although unknown, the lack of a performance change could also be a consequence of movement reorganisation (force orientation, joint angles) via compensatory strategies (Bonnard, Sirin, Oddsson, & Thorstensson, 1994). Thus, future studies should determine how this might be brought about biomechanically. Finally, it cannot be ruled out that IPC had a beneficial effect, resulting in a higher match intensity (and eventually fatigue incurred, which was not controlled for) in the second simulated game after treatment.

Several badminton tests of multiple RSA bouts involving maximal effort accelerations, decelerations and badminton-specific directional changes have been developed to reflect the most intense period of a match (Phomsoupha & Laffaye, 2015). In the current study, we adapted a recently developed test (Phomsoupha et al., 2018) to investigate whether IPC might improve fatigue resistance in a badminton-specific repeated-sprint protocol. Our findings indicate that IPC intervention had no beneficial effect on the ability to break and re-accelerate rapidly during a multiple change of direction task, since repeated-agility performance indices did not differ. In contrast, IPC was shown to improve peak and mean power outputs for the initial 3 cycling efforts of a sequence of twelve 6 s sprints (Patterson et al., 2015). Improved muscle oxygen delivery and extraction has been suggested as key mechanism by which IPC might improve exercise performance (Incognito et al., 2016). Moreover, improved muscle oxygenation profile has been shown to coincide with improved cycling RSA performance (Patterson et al., 2015), as well as repeated maximal knee extensions (Paradis-Deschênes et al., 2016). In line with unchanged performance, the present findings demonstrate no influence of IPC on muscle oxygenation trends during repeated-agility test.

This study is not without limitations. Strength of findings may be limited by the small sample size, albeit in elite players, with the specificity directed towards doubles match-play. Moreover, the test battery was focused towards force production and agility, and did not examine movement re-organization (force orientation, joint angles) or compensatory loading

which might occur as fatigue develops (Bonnard et al., 1994). Lastly, recovery was assessed following simulated match-play, which increases the ecological validity of our findings. However, it cannot be ruled out that IPC could have resulted in higher match intensities in the second simulated game. That said, it is interesting to observe that jump and agility performance did not differ between conditions.

Table 3.
NIRS-related parameters during the repeated-agility test performed after the first (post-1) and the second (post-2) 45-min badminton match with ischemic preconditioning (IPC) or sham (SHAM) interventions implemented between matches.

	IPC		SHAM	
	Post-1	Post-2	Post-1	Post-2
TSI-min				
Baseline	56.7 ± 2.5	52.5 ± 6.3	55.4 ± 4.7	53.9 ± 3.8
RSA-1	30.4 ± 7.8	27.0 ± 10.5	29.7 ± 7.8	28.3 ± 8.2
RSA-2	20.7 ± 9.1	18.2 ± 11.2	19.9 ± 11.4	18.5 ± 10.9
RSA-3	21.2 ± 8.7	18.6 ± 11.4	21.1 ± 12.6	19.8 ± 11.4
RSA-4	20.2 ± 10.3	19.9 ± 11.2	20.7 ± 11.9	20.2 ± 11.7
RSA-5	22.1 ± 11.0	19.2 ± 11.6	21.2 ± 11.0	20.1 ± 11.3
RSA-6	22.4 ± 11.8	21.0 ± 11.0	21.8 ± 11.3	21.2 ± 11.3
TSI-mean				
RSA-1	48.2 ± 3.8	45.1 ± 6.5	47.8 ± 4.0	46.0 ± 5.1
RSA-2	25.9 ± 9.0	23.3 ± 11.4	24.4 ± 10.8	24.3 ± 10.0
RSA-3	25.6 ± 8.5	23.6 ± 11.2	25.1 ± 11.8	24.7 ± 10.5
RSA-4	24.9 ± 10.2	24.6 ± 11.3	25.7 ± 11.9	25.7 ± 10.8
RSA-5	26.6 ± 11.0	23.9 ± 11.4	25.7 ± 11.8	25.1 ± 10.6
RSA-6	27.9 ± 10.8	25.6 ± 10.6	26.7 ± 11.4	25.9 ± 10.8
TSI-AUC				
RSA-1	371 ± 35	350 ± 67	376 ± 25	355 ± 62
RSA-2	195 ± 79	177 ± 97	185 ± 92	181 ± 91
RSA-3	193 ± 76	179 ± 95	193 ± 102	185 ± 95
RSA-4	189 ± 89	188 ± 96	196 ± 102	193 ± 96
RSA-5	200 ± 97	183 ± 99	195 ± 101	188 ± 97
RSA-6	210 ± 93	193 ± 91	205 ± 95	191 ± 96

Data are mean ± SD. TSI, tissue saturation index

CONCLUSION

In summary, the present study indicates that implementing IPC during the recovery period between successive badminton doubles had no significant effect on physical performance and muscle oxygenation trends at the group average level in elite badminton players. However, its use does not follow a 'one-size-fits-all' approach. Perhaps an individually-focused application of IPC (e.g., altering the number of cycles, pressure of cuffs, timing or duration of application into recovery) may reduce 'non-response' to this ergogenic recovery intervention. Future studies should verify if IPC would be beneficial in sub-elite players where the development of fatigue likely is more pronounced. Moreover, future studies examining the effects of match-play fatigue or recovery interventions should extend their measurement tools to assess loading characteristics, movement re-organisation or compensatory mechanisms.

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Original Investigation

Benefits of an intervention programme with racket sports in primary school students. Racket sports in elementary school students

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Abstract

This experimental study is aimed at implementing a one-month racket sports programme within a sample of students aged 9 to 13 years in order to analyze its motivational climate effects during physical education lessons in a primary school context. The intervention programme was carried out on 40 of the 285 participants, the rest of the sample were used for descriptive purposes. The subjects participated voluntarily and were randomly assigned to one of two groups: control (n = 20) and experimental (n = 20). The programme consisted of eight sessions of different racket sports (tennis, paddle, badminton and table tennis). Motivational climate was extracted from the "Questionnaire of Motivational Climate Perceived in Sport" (PMCSQ-2). PMCSQ-2 reported two dimensions, task and ego. Regarding the results obtained, no changes were found in the control group. However, in the experimental group there was a significant increase ($P < 0.05$) in the orientation towards the task (3.22 vs 4.36), leading to the detriment of the ego orientation (3.4 vs 2.25). Thus, racket sports activity seem to be adequate to change motivational orientation towards the task, which has been reported to increase intrinsic motivation and to reduce stress and anxiety in physical education lessons.

Keywords: *Motivational climate; PMCSQ-2; tennis; badminton; paddle.*

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INTRODUCTION

Physical Education content as a school subject is often discussed in public and political debates (Jones and Green, 2015). In recent years, legislative reforms have been made in European education systems (Jones and Green, 2015; Ruin, 2015; Kirk, 2005). Comprehensive educational reforms have changed physical education, but the programmes with racket sports are still rare in primary schools and there are no specific studies of its practical implementation despite its multiple proven benefits (Hoffmann, Brixius, and Vogt, 2018). Racket sports have overwhelming advantages for children (Farrow and Reid, 2016; Jiménez, 2009), since they contribute to the development of perceptive-motor skills, control one's own body and promote learning and health education values. They are also beneficial to the development of tolerance in order to respect individual differences (sex, race, social class and political or religious beliefs), always encouraging an "equal opportunities" education (Jiménez, 2009). According to Guioti, Toledo, and Scaglia (2014), racket sports are an ideal tool for the integration of students with mild intellectual disabilities, favoring their normalization, socialization and non-discrimination by their peers. Similarly, Faber, Bustin, Oosterveld, Elferink-Gemser, and Nijhuis-Van der Sanden (2016) state that anyone can practice racket sports regardless of their physical and intellectual qualities. In addition, racket sports are ideal for improving laterality during the primary education stage (Llanos, 2015) and according to Oja, Kelly, Pedisic, Titze, Bauman, Foster, Hamer, Hillsdon and Stamatakis (2016) they reduce the risk of suffering from a heart attack or cardiovascular disease by 47%. Referring to the reports mentioned above, racket sports should be considered a basic part of the physical education curriculum, supporting the development of motor skills and conditional aspects for children in primary schools (Hoffmann, Brixius, and Vogt, 2018). Based on these findings our study focused on racket sports implementation in primary physical education.

Motivation can be defined as: '*the set of social variables, contextual, performance and persistence in the activity*' (Moreno, Durán, and De la Lastra, 2016). Furthermore, motivation is a crucial factor for the practice of physical exercise and sport, since the athlete's orientation and behavior have been shown to significantly influence the athlete's start, maintenance and abandonment of sports practice (Sandoval, Caracuel, and Ceballos, 2014). The motivation is also useful to optimize sports performance (Sandoval, Caracuel, and Ceballos, 2014). Weinberg and Gould, (1996) collect some actions that will help to raise the motivation of students such as encouraging cooperation and success, using positive reinforcements, establishing achievable challenges and working around the areas of interest to students. The theoretical constructs of motivational climates (Ames, 1992) and goal orientations (Nicholls, 1989) are essential in understanding children's experiences with sports since both emphasize the importance of motivation in the process of performing regular physical activity. All of the aforementioned information, they are discussed below.

The theory of goal perspectives (Ames, 1992; Nicholls, 1984, 1989) attaches great importance to the role played by cognitive processes associated with motivational responses. Success and failure are considered to be psychological states that can only be identified when based on the goal of the subject's behavior (Sandoval, Caracuel and Ceballos, 2014). Nicholls (1984) defends the idea that the subjects in achievement situations act under two goal perspectives (task and ego involved). Nicholls (1984) also states that task and ego involved relate to the way in which subjects define success, failure and judge their level of competence. When a person is task involved, they will show behaviors, affections and cognitions that will lead to maximum motivation, independently of one's perception of ability. Nicholls (1984) suggests that a task-involved goal will bring effort, low anxiety, high fun and intrinsic interest in the activity. Instead, considering subjects with ego-involved, if the perception of the ability is high, an adaptive model of achievement will be developed but, on the contrary, if the perceived ability is low, there will be a little adaptive model of achievement. Subsequently, ego involved is characterized by reduced effort, high anxiety and decreased intrinsic motivation and persistence (Nicholls, 1984). It proved that the state of goal involvement of the individual appears by variations in the degree of orientation to the ego and task, in addition to the variations of the motivational climate in which the behavior takes place (Balaguer, Guivernau, Duda, and Crespo, 1997). Most of the research conducted on this topic has been carried out in the school environment (aged 9 to 16 years) (McLaren, Newland, Eys, and Newton 2017; Liukkonen, Barkoukis, Watt, and Jaakkola, 2010). There is evidence to show that the motivational climate varies if it is a team or individual sport (racket sports), being individual sports more likely to foster the ego involved (Tello, Martínez, Núñez, and Calvo, 2010).

As the motivational climate decisively influences the initiation and maintenance of physical activity (Sandoval, Caracuel, and Ceballos, 2014) and the need for interventions where importance is given to personal development and effort (González-Valero, Zurita-Ortega, and Martínez –Martínez, 2017), this intervention is proposed, where the teacher will be in charge of creating a motivational climate based on the process and personal benefit (González-Valero, Zurita-Ortega, and Martínez-Martínez, 2017). In addition, a gap in the literature is detected when analysing how a racket sports programme can influence motivational climate since it is a type of sports practice infrequently used during the primary stage (Hoffmann, Brixius, and Vogt, 2018).

The principal aim of the study is to implement a one-month racket sports programme, along with other interventions with racket sports (Faber, Pion, and Nijhuis-Van der Sanden, 2019; Tsetseli, Malliou, Zetou, Michalopoulou, and Kambas, 2010), in a sample of students aged 9 to 13 years to analyze its effect on motivational climate during physical education classes in elementary school. Also, as a secondary objective of the present research, it compared the obtained levels of motivation in relation to the sport practice outside school, racket sports practice, type of racket sport and gender. It is hypothesized that our intervention with racket sports will reduce the ego involved and increase the task involved in a sample of Spanish students during physical education classes.

METHODOLOGY

Participants

For this study, data were collected from 285 participants, of which 54.7% (n = 156) were boys and 45.3% (n = 129) girls. They were students attending different schools in the city of Granada with an age range from 9 to 13 years old. The intervention programme was carried out with only 40 of the 285 participants because it could only be done in one of the schools selected. Participants voluntarily performed the study and were randomly assigned to one of two groups: control (n = 20) and experimental (n = 20). The data collected from the rest of them was used to describe the motivational climate based on the gender, sport practice outside the school, the practice of racket sport and type. All tests completed by the participants had the approval of the Ethics Committee of the University of Granada. Additionally, this study complied with the ethical standards of the World Medical Association Declaration of Helsinki signed in 2013.

Procedures

For the collection of data, an official letter was first delivered from the University of Granada to the different schools; more precisely, from the Department of Musical Didactics, Plastic and Corporal Expression in the Faculty of Educational Sciences. With this official letter and with the aim of developing the present research study, permission from the schools was requested in order to legally gather data. Parents were also asked to sign a written informed consent. The data collection process lasted two sessions: one for the "pre-test" and the other one for the "post-test". It took forty-five minutes for each participant to complete the questionnaires. Study participants collectively conducted the questionnaires in the classroom during a school day. By means of a record sheet, information from gender, practice of sport outside school, practice of racket sport and type is collected.

The motivational climate of the participants was analyzed through the Questionnaire of Motivational Climate Perceived in Sport (PMCSQ-2) developed by Newton and Duda (1993); it presents evidence of its validity and reliability on male and female school students (aged 9 to 16 years), in different sports such as soccer, racket sports, athletics, basketball, volleyball and dance (Balaguer, Guivernau, Duda, and Crespo, 1997; Newton, Duda, and Yin 2000; Hancox, Quested, Viladrich, and Duda, 2015; McLaren, Newland, Eys, and Newton 2017). In the present study, the Spanish version was applied (Gónzalez-Cutre, Sicilia, and Moreno, 2008) since the sample used was made up of Spanish children. Moreover, the Spanish version of the questionnaire has been equally used in other research studies (Coterón-Lopez, Franco, Pérez-Tejero, and Sampedro, 2013), to check the effect of motivational climate in children. This consists of 33 items with a Likert scale of 5 options where 1 means "totally disagree" and 5 "strongly agree". The Spanish version of the PMCSQ-2 reported two dimensions: task involved (mean of items 1, 4, 5, 8, 10, 11, 14, 16, 19, 20, 21, 25, 28, 30, 31, 32 and 33) and ego involved (mean of items 2, 3, 6, 7, 9, 12, 13, 15, 17, 18, 22, 23, 24, 26, 27 and 29).

In addition, after collecting the sample of the "pre-test", a racket sports programme was carried out in a primary school located in Granada during the hours of physical education classes, which lasted eight sessions of racket sports practice (two 45 min sessions per week) and one introductory theory session (1 hour) to explain the dynamics of the programme to the participants. The sessions were divided into a 10 min warm-up, 30 min for the main part and 5 min to return to calm. The duration of the programme was 5 weeks, like other similar interventions with racket sports in schools (Faber, Pion, and Nijhuis-Van der Sanden, 2019; Tsetseli, Malliou, Zetou, Michalopoulou, and Kambas, 2010). The racket sports chosen for the programme were based on the study of Hoffmann, Brixius, and Vogt (2018) who conclude that the most practical sports in primary school are badminton and tennis. The other selected sports were paddle and beach tennis with a wooden racket, since we had to adapt to the possibilities of the school hosting the intervention. Two sessions were held for each of the aforementioned racket sports.

The development of the sessions was fully adapted to the methodology called "modified technical model". According to Duaigues and Fuentes-Guerra (2010), this methodology is the most frequently used in teaching racket sports during the initiation stage, which is characterized for maintaining a central position of the teacher; considering tasks, the choice of them without opposition and utilization of positive reinforcements and corrections takes place. Based on the model of Duaigues and Fuentes-Guerra (2010) the most valuable aspect during the intervention will be the progression of teaching in technical aspects.

Variables

Task and Ego involved: dimensions extracted from the questionnaire PMCSQ-2.

Gender: through the dichotomous option of "male" or "female".

Sports practice outside school: sport practice was registered, by means of the dichotomous option of whether or not it was practiced outside school, using a record sheet where participants were encouraged to choose between the option 'yes', as long as the student did the physical activity outside the school, or 'no', if they did not practice it.

Racket sport practice: racket sport practice was obtained through the dichotomous option of whether or not it was practiced, using a registration form.

Type of racket sport: type of racket sport was divided into four options: I) tennis, II) paddle tennis, III) table tennis and IV) badminton.

Statistical analysis

To carry out the statistical analysis and the execution of tables and figures, the IBM SPSS Statistics Data Editor Version 20 programme was used. To check the normality of the variables, the Kolmogorov-Smirnov normality test was administered. One Way ANOVA and the post hoc analysis of Bonferroni was used as tool to compare the means of task and ego involvement varying on gender, sports practice outside school, racket sport practice and type of racket sport. Additionally, One Way ANOVA and analysis of Bonferroni was also used to compare the means of task and ego involved between the pre and post-test in the control group and the experimental group. The level of significance used was $p<0.05$. The internal consistency of the study is demonstrated by Cronbach's alpha ($\alpha = 0.809$). The effect size was calculated using the freeware Psychometric (Lenhard and Lenhard, 2016). D-Cohen was used as follow: 0.2 to 0.4 small effect, 0.5 to 0.7 medium effect and > 0.8 strong effect (Cohen, 1988).

RESULTS

The total sample (n=285) was composed of 54.7% of boys and 45.3% of girls. The analysis of the frequency in the practice of out-of-school sports shows that 22.8% of the sample did not practice any sport outside school, while 77.2% did so. With respect to the frequency in the practice of racket sports, 77.5% of the sample did not practice any racket sport, whereas a 22.5% did. In relation to the type of racket sport practiced by each individual, 77.5% practiced none, while 11.9% practiced paddle, 8.1% tennis, 1.8% table tennis and 0.7% badminton. The average values (mean ± standard deviation) obtained in the task orientation was 3.87 ± 0.72 and for ego orientation 2.66 ± 0.88.

Table 1 presents the relation between motivational climate and gender. No statistically significant differences were found among task orientation or ego orientation ($p > 0.05$). The ANOVA, used to compare the motivational climate in relation to the practice of extra-curricular sport, revealed significant differences in task orientation ($p = 0.016$), since practitioners are more oriented towards this option. The effect size was small (Table 2). Statistically significant differences were again found between the motivational climate and the practice of racket sport, specifically in the ego orientation. Those participants who did racket sports were also more oriented towards ego orientation, resulting in the effect size being small (Table 2).

Table 2 shows the relation between task and ego involved with the type of racket sport practiced but there are no significant differences.

Table 1.
Comparison of task and ego involved based on gender, sports practice outside school and racket sports practice of all the participants.

	N	Sex (N)			
		Male (156)	Female (129)	p	d Cohen
Task	285	3.91 ± 0.722	3.82 ± 0.724	0.262	0.189
Ego		2.64 ± 0.856	2.69 ± 0.902	0.645	0.048
		Extracurricular sport (N)			
		Yes (220)	No(65)	p	d Cohen
Task	285	3.93 ± 0.714	3.68 ± 0.727	0.016*	0.347
Ego		2.69 ± 0.877	2.55 ± 0.872	0.232	0.251
		Practice of racket sport (N)			
		Practising(64)	Nonpractising(221)	p	d Cohen
Task	285	3.86 ± 0.703	3.87 ± 0.730	0.853	0.105
Ego		2.89 ± 0.911	2.59 ± 0.857	0.016*	0.339

*P < 0.05; **p < 0.01; ***p < 0.001; *d Cohen: small effect size (0.2 to 0.4); intermediate effect (0.5 to 0.7); large effect (>0.8); *Means ± standard deviation

Regarding the analysis of the intervention with racket sports, (n=40; control group = 20 and experimental group = 20) relevant comparisons are displayed in Figure 1. It compares the average statistical values of task orientation and ego orientation that were obtained in the "pre-test" and the "post-test" within the control group and the experimental group. No significant differences ($p > 0.05$) were found, neither in the task, nor ego in the control group. In the experimental group after the intervention, task orientation was equal to 4.36 (0.61) and ego orientation to 2.25 (0.58). Statistically significant differences were found ($p < 0.001$) between the value of the task orientation obtained in the pre-test and the post-test, being the effect size strong ($d = 2.23$). There were also significant differences ($p < 0.013$) between the value of the Ego orientation in the pre-test and post-test being the effect size strong again ($d = 2.01$) (Cohen, 1988).

Table 2.
Task and ego involved depending on the type of racket sport practiced by all the participants.

Motivational climate	Sport (N)	Means ± SD	P
Task involved	None(221)	3.87 ± 0.73	0.915
	Tennis(23)	3.89 ± 0.63	
	Paddle(34)	3.85 ± 0.75	
	Table tennis(5)	3.61 ± 0.79	
	Badminton(2)	4.14 ± 0.87	
Ego involved	None (221)	2.59 ± 0.86	0.125
	Tennis(23)	2.74 ± 0.99	
	Paddle(34)	2.98 ± 0.87	
	Table tennis(5)	3.08 ± 1.05	
	Badminton(2)	2.65 ± 0.57	

*SD: Standard deviation; *p < 0.05;**p < 0.01; ***p < 0.001

DISCUSSION

In the present investigation, conducted on a sample of 285 elementary school students, it was initially found that approximately three quarters of them practiced extra-curricular physical activity, this result coinciding with the previous study carried out by Castro, Zurita, Martínez, Chacón, and Espejo (2016). This high percentage in extra-curricular sports practice that we found was probably due to the great investment made in sport facilities and, therefore, in infrastructures, during recent years; this helped access for young people. The results also indicate that approximately one fifth of the sample who play sports outside school choose a racket sport, as shown in the studies of Molla (2007) and García (2006), since primary school students have a preference for other sport disciplines such as football, handball or basketball (Luengo Vaquero, 2007). Focusing on the type of racket sport practiced, the results obtained demonstrate that the practice of paddle predominates, coinciding with its explosion in the last decade and closely followed by tennis. These results support previous research by Garcia (2006) and Molla (2007), that showed that the most practiced racket sports are paddle and tennis in this order.

When evaluating the average statistical values of the motivational climate, it is verified that significantly higher scores were achieved in the task climate than in the ego climate; this data coincides with that obtained by Méndez-Giménez, Fernández-Río, Cechini, and González (2013) and González-Cutre, Sicilia, and Moreno (2011) in his studies with students of the same age as our research. These results indicate that the participants of the sample give more importance to the process than to the result. This favours the involvement in physical education lessons and the adherence to physical activity practice as importance is given to personal growth and effort causing a reduction of stress, anxiety and an increase in intrinsic motivation of the students (Méndez-Giménez, Fernández-Río, Cechini, and González, 2013).

With respect to the motivational climate, its relation with different socio-demographic variables such as gender, sport practice outside school, racket sports practice and the type of racket, are also present. The results show significant differences in the case of the task orientation, with their average values being higher among those who practice sport outside school. In the same way, Mora, Cruz, and Sousa (2013) pointed out that this could happen due to a greater adherence to the students' sports practice. There were also significant differences among participants who practice racket sports, since higher ego orientation values were obtained, probably because most racket sports are practiced individually or in pairs and, therefore, they do not encourage social relationships as opposed to team sports (Balaguer, Guivernau, Duda, and Crespo, 1997). While no differences were found in the relation of motivational climate with gender, it was not the case in the study carried out by Florez, Salguero, Molinero, and Marquez (2011), who found higher ego orientation in boys' than in girls, possibly caused by a higher age range in their sample, which has been shown to affect the motivational climate (Méndez-Giménez, García-Romero, and Cechini, 2018). Méndez-Giménez, García-Romero and Cechini, (2018), demonstrated that the age range from 13 to 14 years shows a greater sensitivity to variations in the motivational climate and perhaps, for this reason, our results do not coincide with those of Florez, Salguero, Molinero, and Marquez (2011). With regard to the type of racket sport practiced, no significant differences were observed. We have not found any reference that could explain this issue.

Although the effects of an intervention with racket sports in a sub-sample were analyzed, there were no changes in the control group or in task or ego involved. However, in the experimental group the task involved values significantly increased, whereas the ego involved values significantly decreased. This demonstrates, as we hypothesized, that racket sports in an educational environment will bring effort, low anxiety, high fun and intrinsic interest to the activity. Our results could be extended to other countries since the intrinsic motivation in sport has been tested in different European countries (France, Greece, Norway and England) giving similar results (Viladrich et al., 2013). Other sports disciplines like soccer or handball tend to promote the task involved because they are team sports and it is demonstrated that they favor this dimension (Balaguer, Guivernau, Duda, and Crespo, 1997; Gómez-López, Granero-Gallegos, Baena-Extremera, and Abraldes, 2014; Møllerløkken, Lorås, and Pedersen, 2017). Therefore, introducing racket sports into school would be an appropriate way to use individual sports during physical education classes in elementary education. Besides this, our results support the recommendation of Iglesias (2016) who states that using racket sports in primary education favours the acquisition of basic skills such as hygiene and health values, as well as tolerance; he also uses physical education and sports as a means of promoting personal and social growth. The chosen methodology (modified technical model) turned out to be appropriate for the initiation into racket sports, just as Duaigues and Fuentes-Guerra, (2010) explained in their study. In this respect, the increases in the task climate after the intervention with racket sports also guarantee the success with the proposed methodology since this is a demonstration that improves the intrinsic motivation of students during physical education lessons.

Regarding the strengths of this study, this is a pre-post experimental research in which the effects on the motivational climate of a racket sports programme were evaluated; this is a novelty due to the aforementioned gap in the literature and given the need for interventions based on the process and personal benefit of the students. Despite careful consideration, the present study comprises a few limitations. A racket sports programme of just 5 weeks duration was held because students must meet the annual physical education curriculum. A longer programme could show better effects on the motivational climate of the students. For future research, the aim is to increase the sample size and the duration of the programme, in addition to verifying how long the effects on the motivational climate are maintained.

CONCLUSIONS

In conclusion, our intention was to check the effects of a racket sports programme on the motivational climate of primary school students, contributing to the dissemination of knowledge in this area. It is evident how our introduction to the racket sports has significantly increased the orientation towards the task, leading to the detriment of the ego involved. Racket sports seem to be adequate for changing motivational orientation towards the task which has been reported to increase intrinsic motivation in physical education. This finding can be useful for all physical education teachers who are willing to improve the motivational climate in their classrooms.

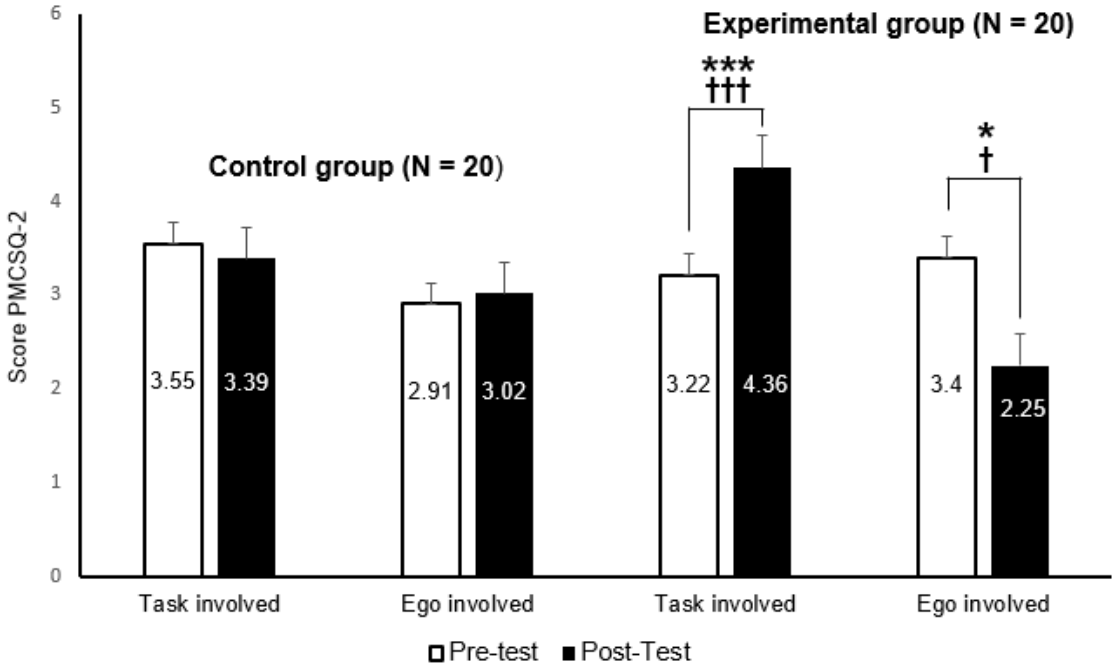

Figure 1. Comparison of the motivational climate before and after its implementation in the control group and the experimental group. *p < 0.05; **p < 0.01; ***p < 0.001; † small effect size (0.2 to 0.4); †† intermediate effect (0.5 to 0.7); ††† large effect (>0.8).

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Original Investigation

Comparing Thirty30 Tennis with Traditional Tennis

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Abstract

Thirty30 is a shorter format of tennis where games start at 30-30. This means that a greater proportion of points are game points or break points than would be the case in traditional tennis. The purpose of the current paper is to compare the probability of players of different abilities winning games, sets and matches between Thirty30 tennis and traditional tennis. This is done using probabilistic models of each format of tennis. The results show that there is reduced dominance of the serve and a greater probability of upsets in Thirty30 tennis than in traditional tennis. The models are also experimented with, adjusting the probability of winning points where the point is a game point or a break point. The paper shows that such scoreline effects have a greater impact in Thirty30 tennis than they do in traditional tennis. This has implications for player preparation for Thirty30 tennis.

Keywords: *Probabilistic model, scoreline effect, rule changes.*

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INTRODUCTION

As sports develop over time, rules are changed for a variety of reasons including commercial pressures, accounting for technological advances in equipment and due to physical changes in players competing in sports (Williams, 2008). The main commercial pressure is to retain audience levels for the sport, both live at sports venues and through media. Sports with larger audiences enjoy greater sponsorship from commercial organisations due to the exposure the sports bring to the sponsors. Therefore, some rule changes are developed specifically to maintain or increase the excitement of the sport.

The duration of contests has also been modified to retain audiences. For example, shorter formats of cricket and netball have been developed. These shorter formats of matches can lead to an increased chance of unexpected results where lower ranked teams and players win matches against higher quality opposition. This may be due to the shorter performances being less representative of teams' and players' abilities than longer performances. The increased uncertainty that comes with shorter formats of sports may make sports more appealing to audiences than if the sports were highly predictable. However, the uncertainty of the sport also needs to be balanced with a reasonable chance of the highest ranked performers being successful and reaching the latter stages. There is debate about what fairness in sport is. Torres (2014, p.106) describes sport as a "meritocratic practice" where quality of performance should be rewarded. An alternative view is that handicaps should be used to give performers of different abilities an equal chance of winning. Fairness in such sports is concerned with how well handicapping systems achieve an equal chance of winning (McHale, 2010).

A shorter version of netball (Fastnet) was developed by reducing the duration of quarters from 15 minutes to 6 minutes. Shorter versions of cricket have been developed by restricting the number of overs per innings to 50 and 20 in One-Day cricket and Twenty20 cricket respectively. These formats have been highly successful in increasing audiences and attracting sponsorship. However, traditional 60 minutes netball remains the dominant format of the game and many consider test cricket to be the most prestigious format to participate in.

Tennis matches are not contested over a fixed duration of time or number of points. Instead, matches are structured into hierarchies of sets, games and points with defined conditions for winning that mean that both the number of points played and the time duration of matches vary within the same format of the sport. Therefore, rule changes aimed at reducing the duration of tennis matches will modify the criteria for games and sets to be won. Traditional tennis involves sets being won where a player has won 6 games and at least 2 more games than the opponent. Tennis matches within the Grand Slam tournaments are the best of 3 sets in women's singles or 5 sets in men's singles. The requirement to win at least 2 more games than the opponent has led to lengthy sets in tennis. Therefore, different forms of tie-break were introduced with the format currently used in the US Open being used since 1975. This tie-break involves both players serving and is played until one player has won at least 7 points and at least 2 more points than the opponent. The US Open played tiebreaks at 6-6 in all sets, while the other Grand Slam tournaments initially used tie-breaks at 8-8 except in the final set. Wimbledon, the French Open and the Australian Open moved the tie-break to 6-6 in 1979 but did not use tie-breaks in the final set. There have still been some very long final sets with concern expressed for player welfare and chances of winning subsequent matches within the tournament (Standard, 2016). In 2019, Wimbledon introduced the tie-break to 7 points for matches where the final set reached 12-12. In the same year, the Australian Open introduced a tie-break to 10 points where the final set reached 6-6; a player needs to win at least 10 points and at least 2 more points than the opponent to win this type of tie-break. The tie-break to 10 points was used in the Tie-Break Tens format, prior to its use in the Australian Open. There are Tie-Break Tens competitions where the matches are composed of a single tie-break to 10 points. The Laver Cup uses the tie-break to 10 points as a deciding 3rd set.

A further shortened version of tennis is Fast4 tennis where sets are played to 4 games using a tie-break to 5 points if the score reaches 3-3. A major difference between traditional tennis games and games in Fast4 tennis is that when a game reaches a score of Deuce, the next point decides the game without a need for a player to win at least 2 more points than the opponent. If a tie-break to 5 points reaches a score of 4-4, the next point decides the tie-break. A further feature of Fast 4 tennis is that the player who serves the 9th point of a tie-break to 5 points is decided by a coin toss. The Fast4 tennis format is used at a range of levels from grass roots tennis right up to major international tournaments such as the Hopman Cup.

The current research investigates a further format of tennis called Thirty30 tennis. Sets within Thirty30 tennis are won by the first player to reach 6 games and be 2 games ahead of the opponent, or by a score of 7-5 or by a tie-break if the set reaches a score of 6-6. The differences between Thirty30 tennis and the sets played in Grand Slam tennis are that the games start at 30-30 rather than Love-All and that the tie-breaks differ. The tie-breaks in Thirty30 tennis are played to 5 points but differ from those played in Fast4 tennis in that the player who served first in the set serves the deciding point if the tie-break reaches 4-4. The exception to this is the final set of a Thirty 30 match where a player must finish at least 2 games ahead of the opponent to win the match. The claim of those who created Thirty30 tennis is that "every point really counts" (Milne, 2018). Certainly, points from 30-30 have been shown to be more important than points before 30-30 in traditional tennis games (Morris, 1977).

A topic of interest with respect to any rule change in sport is how it effects the chances of players of different qualities winning matches. Probabilistic models have been used to estimate the probability of a player winning games, sets and matches in different formats of tennis. These models are ultimately in terms of the probability of the serving player winning a point on serve. Croucher (1982) expressed the probability of winning a game on serve given the probability of winning a point on serve. Further work by Croucher (1986) provided the conditional probability of winning a game from each scoreline within a game. Further models have been produced for traditional sets (Pollard, 1983), tie-breaks to 7 points (Pollard, 1983), Tie-Break Tens tennis (O'Donoghue and Simmons, 2019), games, sets and matches in Fast4 tennis (Simmonds and O'Donoghue, 2018) and other short formats of tennis (Pollard and Barnett, 2018). These models have shown that lower ranked players have a higher chance of winning sets and matches in shorter forms of tennis than they do in traditional tennis matches. A limitation of these models is that they assume the probability of winning a point is independent of the scoreline within games, sets and matches and independent of the outcome of preceding points within games. However, Klaasen and Magnus (2001) have found that the chance of winning a point in professional tennis is only inflated by 0.3% or 0.5% in women's and men's singles respectively when the previous point is won. Furthermore, Newton and Aslam (2006) showed that the probabilistic models for tennis are robust to violation of the assumption of independence of points. O'Donoghue (2001) compared the proportion of points won at each score from Love-All to Deuce, finding no impact of points score on the proportion of points won.

Thirty30 tennis contains more pressure points than other formats of tennis because every other point within a game will either be a game point or a break point; in the current paper we use the term "critical points" to cover game points and break points. If there are players who perform better or worse during critical points than they do during other points, then it is particularly important that this is addressed by any models being used to compare Thirty30 tennis with traditional tennis. Therefore, the purpose of the current paper is to compare the probability of winning games, sets and matches between Thirty30 tennis and traditional tennis when the probability of winning critical points differs from the probability of winning other points. This is done for a realistic range of probabilities of winning points on serve. The paper represents traditional tennis matches using the US Open format where a tie-break to 7 points is used if the final set reaches a score of 6-6.

The models

The models used in the current research are extended versions of Croucher's (1982) model for winning a game in traditional tennis, the conditional probability of winning a tennis game from a score of 30-30 (Croucher, 1986), the probability of winning a tie-break to 7 (Fisher, 1980) and the probability of winning a tie-break to 5 (Simmonds and O'Donoghue, 2018 modified).

Figure 1 shows the possible ways of winning a game in traditional tennis. Croucher's (1982) model expresses the probability of the serving player winning a game, G, as equation (1) where p is the probability of the serving player winning a point and q (= 1 – p) is the probability of the receiving player winning a point. Figure 2 shows the possible ways of winning and losing a Thirty 30 tennis game with the probability of the serving player winning the game, G, shown in equation (2).

$$G = p^4(1 + 4q + 10q^2) + 20p^5q^3/(1 - 2pq) \quad (1)$$

$$G = p^2/(1 - 2pq) \quad (2)$$

Figures 1 and 2 extend Croucher's (1982, 1986) models by distinguishing between game points, break points and other points as follows:

The probability of the server winning or losing a break point are r and s (= 1 – r) respectively

The probability of the server winning or losing a game point are u and v (= 1 – u) respectively

The probability of the server winning or losing any other point are p and q (= 1 – p) respectively

Replacing p and q by r and s within break points and by u and v within game points extends equation (1) to equation (3) for traditional tennis games. Similarly, equation (2) is extended to equation (4) by introducing separate probabilities for break points, game points and other points.

$$G = p^3u(1 + v + 3q + v^2 + 3qv + 6q^2) + (p^3v(v^2 + 3vq + 6q^2) + q^3r(r^2 + 3rp + 6p^2))\ pu/(1 - pv - qr) \quad (3)$$

$$G = pu/(1 - pv - qr) \quad (4)$$

Traditional tennis sets and sets in Thirty30 tennis use a tie-break at 6-6. Let A be the player who serves first in a set and B be the opponent. Equation (5) represents the probability of the player A winning the set, S_A, in terms of the probability of players A and B winning service games (G_A and G_B respectively) and losing service games (H_A and H_B respectively). Note that H = 1 – G for each player's service games. T_A is the probability of player A winning a tie-break to 7 points and uses the model expressed by Fisher (1980). T_A in equation (5) is replaced by $G_AH_B/(1 - G_AG_B - H_AH_B)$ for the final set of a Thirty 30 tennis match. This is the sum of a geometric progression giving the conditional probability of player A winning the final set by two games given that the set has reached a score of 6-6.

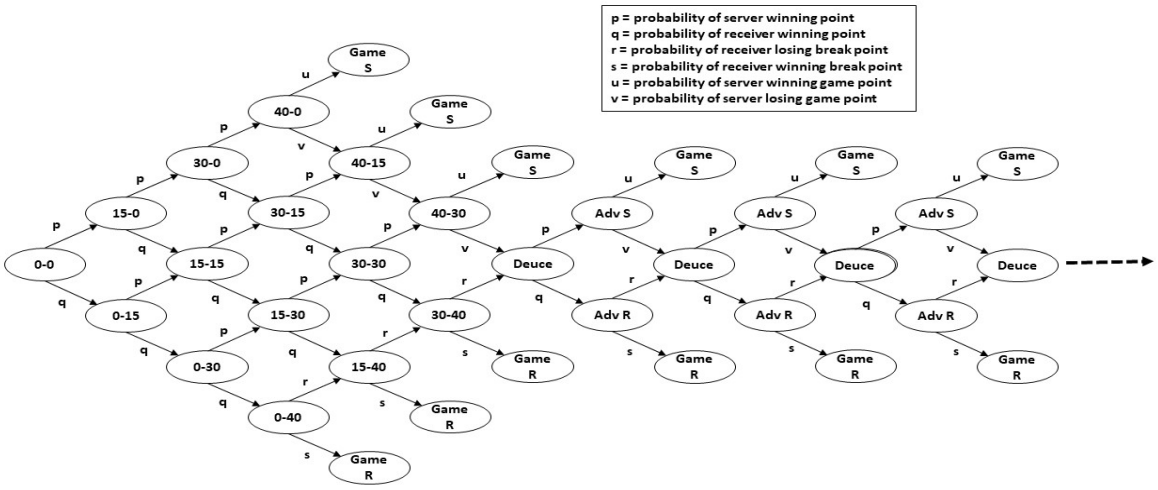

Figure 1. Pathways to winning or losing a traditional tennis game.

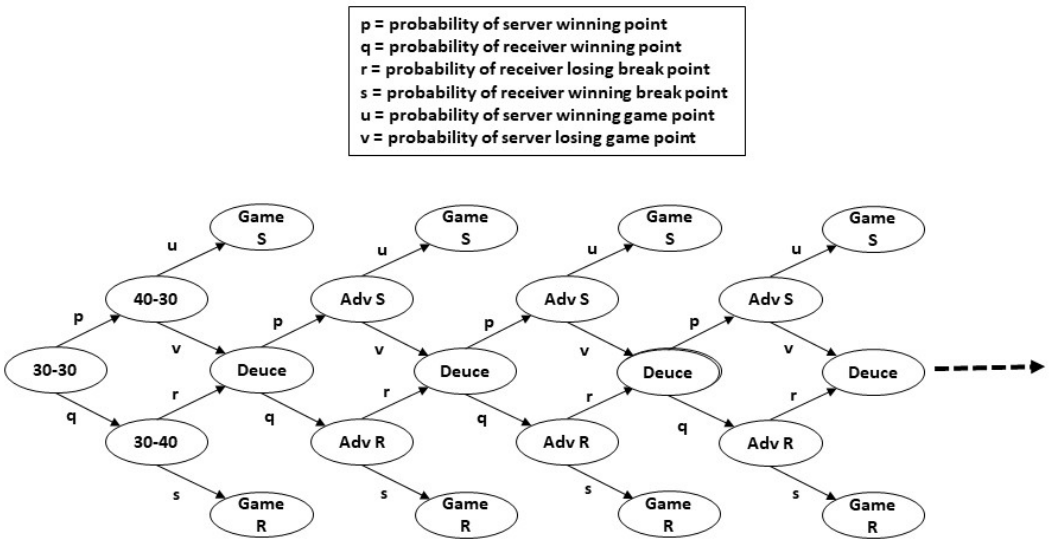

Figure 2. Pathways to winning or losing a Thirty30 tennis game.

$$
\begin{aligned}
S_A = {} & G_A^3H_B^3 + 3G_A^4H_B^2G_B + 3G_A^3H_AH_B^3 + 3G_A^4H_B^2G_B^2 \\
& + 12G_A^3H_AH_B^3G_B + 6G_A^2H_A^2H_B^4 + 4G_A^5H_BG_B^3 \\
& + 24G_A^4H_AH_B^2G_B^2 + 24G_A^3H_A^2H_B^3G_B + 4G_A^2H_A^3H_B^4 \\
& + G_A^5H_BG_B^4 + 20G_A^4H_AH_B^2G_B^3 + 60G_A^3H_A^2H_B^3G_B^2 \\
& + 40G_A^2H_A^3H_B^4G_B + 5G_AH_A^4H_B^5 + G_A^6H_BG_B^5 \\
& + 25G_A^5H_AH_B^2G_B^4 + 100G_A^4H_A^2H_B^3G_B^3 + 100G_A^3H_A^3H_B^4G_B^2 \\
& + 25G_A^2H_A^4H_B^5G_B + G_AH_A^5H_B^6 \\
& + (G_A^5G_B^5 + 25G_A^4H_AH_BG_B^4 + 100G_A^3H_A^2H_B^2G_B^3 + \\
& \quad 100G_A^2H_A^3H_B^3G_B^2 + 25G_AH_A^4H_B^4G_B + H_A^5H_B^5)(G_AG_B \\
& \quad + H_AH_B)T_A
\end{aligned}
\tag{5}
$$

The probability of winning a set is not affected by who serves first in traditional tennis. Therefore, the probabilities of player A winning a best of 3 and 5 sets match, M_A, in traditional tennis is given by equations (6) and (7) respectively.

$$M_A = S_A^2 + 2S_A^2(1 - S_A) \tag{6}$$

$$M_A = S_A^3 + 3S_A^3(1 - S_A) + 6S_A^3(1 - S_A)^2 \tag{7}$$

The model for the 5 point tie-break used in Thirty30 tennis differs slightly from that used in Fast 4 tennis (Simmonds and O'Donoghue, 2018) in that the player, A, who served first in the set, and hence who served first in the tie-break, serves the 9th point of the tie-break. The model for the probability of player A winning this form of tiebreak, T_A, is given by equation (8) where p_A and q_A (= 1 – p_A) are the probabilities of player A winning and losing points on their serve during the tie-break and p_B and where q_B (= 1 – p_B) are the probabilities of player B winning and losing points on their serve during the tie-break.

$$T_A = p_A^3q_B^2 + 2p_A^3q_B^2p_B + 3p_A^2q_Aq_B^3 + 3p_A^3q_B^2p_B^2 + 9p_A^2q_Aq_B^3p_B + 3p_Aq_A^2q_B^4 + 4p_A^4q_Bp_B^3 + 18p_A^3q_Aq_B^2p_B^2 + 12p_A^2q_A^2q_B^3p_B + p_Aq_A^3q_B^4 + p_A^5p_B^4 + 16p_A^4q_Aq_Bp_B^3 + 36p_A^3q_A^2q_B^2p_B^2 + 16p_A^2q_A^3q_B^3p_B + p_Aq_A^4q_B^4 \quad (8)$$

The player to serve first in a set alternates in a Thirty30 match and the player who serves first does have a higher probability of winning the set where both players have an equal probability of winning a point on serve that is greater than 0.5. Let A be the player who serves first in the first set and B be the opponent. S_A and S_B represent the probability of players A and B winning a set where they serve first respectively. Tie-breaks are not used in the final set of Thirty30 tennis. Therefore, F_A is used to represent the probability of player A, who serves first in the final set, winning this set. Equations (9) and (10) are the models for the probability of player A winning a Thirty30 match, M_A, when the match is the best of 3 and 5 sets respectively.

$$M_A = S_A(1-S_B) + S_AS_BF_A + (1-S_A)(1-S_B)F_A \quad (9)$$

$$M_A = S_A^2(1-S_B) + 2S_A(1-S_A)(1-S_B)^2 + S_A^2S_B(1-S_B) + S_A^2S_B^2F_A + (1-S_A)^2(1-S_B)^2F_A + 4S_AS_B(1-S_A)(1-S_B)F_A \quad (10)$$

Analysis process

This paper contains two stages of analysis. The first stage is a summary of differences in the probability of winning games, tie-breaks, sets and matches between traditional and Thirty30 tennis. The second stage examines the impact of performing better or worse during critical points on the probability of winning a game. This research was approved by the Natural Science (Sport) panel of the Ethics Committee of the School of Sport and Health Sciences of Cardiff Metropolitan University (Project STA-2757).

The probability of winning games, sets and matches in the two formats of tennis is analysed using realistic values for the probability of points being won by the serving player. A recent study of the Australian Open revealed that players win more points when serving than receiving in both women's and men's singles (Reid, Morgan, and Whiteside, 2016). The Australian Open is played on a surface which is faster than that of the French Open, similar to the US Open and slower than that of Wimbledon. The terms "faster" and "slower" here are used to broadly represent the coefficients of friction and restitution that influence how much speed the ball loses in the horizontal and vertical directions when it bounces. The proportion of points won when serving at the Australian Open is greater than that observed at the French Open and less than that observed at Wimbledon and the US Open (O'Donoghue and Ingram, 2001; O'Donoghue, 2013). Therefore, values from the Australian Open are used to represent typical Grand Slam performance. Gale's (1971) formula can be applied to the proportion of points where the first serve is in, the proportion of points won when the first serve is in and the proportion of points won when a second serve is required. These are derived from Reid et al.'s (2016) results and yield a probability of 0.532 for the serving player winning a point in women's singles and 0.612 in men's singles. The winning player's proportion of points won on serve is typically 0.1 greater than that of losing players' in both women's and men's singles at all four Grand Slam tournaments (O'Donoghue, 2013). Therefore, values of 0.582 and 0.482 are used for the probability of winning and losing players winning points on serve in women's singles and 0.662 and 0.562 are used for the probability of winning and losing players winning points on serve in men's singles. While the outcome of these matches is known, we use these probabilities to determine the probability each player had of winning games, tie-breaks, sets and matches at the beginning of these units of play.

The second stage of analysis considers the effect of performing better or worse on critical points than on other points. This needs to be done using a realistic range of values for the probability of winning points on serve. O'Donoghue (2013) reported on the distributions of the proportion of points won on serve in women's and men's singles at all four Grand Slam tournaments. Normal distributions were found in six of the eight events. This allows a range of probabilities that covers 95% of performances to be estimated for each event (mean±1.96 SD). The lowest lower limit of the middle 95% of any of these distributions is 0.315 for the losing players in women's singles matches at the US Open. The highest upper limit is 0.817 for the winning player in men's singles matches at Wimbledon. Therefore, the analysis of differing performances during critical points uses a range of probabilities of winning a point on serve from 0.3 to 0.8. It is also necessary to adjust the probabilities of winning points on serve by realistic differentials when players face critical points. O'Donoghue (2012) compared receiving performances by the World's top 4 men's singles players during break points and non-break points in Grand Slam matches. One of the player's percentage of points won during break points was 5.0% higher than during non-break points while another's was 5.1% lower. The other two players were in between these values. These differences also reflect realistic differences on game points because an opponent is serving a game point when one of these players faces a break point. Therefore, the current study adds and subtracts 0.05 to and from the probability of winning a point during critical points.

RESULTS

Figure 3 shows that there is a higher probability of a service break occurring in Thirty30 tennis than in traditional tennis when the serving player has a probability of winning a point on serve greater than 0.5. Table 1 shows the probabilities of winning games, tie-breaks, sets and matches in traditional and Thirty30 tennis. These use probabilities of winning and losing players winning points on serve derived from Reid et al.'s (2016) study to determine their probabilities of winning games, tie-breaks, sets and matches at the beginning of these units of play. Probabilities of winning points that are greater than 0.5 inflate to higher probabilities of winning service games in traditional tennis than they do in Thirty30 tennis. Players who win more points on serve than their opponents also have a higher chance of winning tie-breaks, sets and matches in traditional tennis than in Thirty30 tennis.

Table 2 shows the probability of the serving player winning a game when the probability of winning a point differs during critical points to the probability of winning other points in the game. The impacts of performing differently during critical points than other points are larger in Thirty30 tennis than in traditional tennis in all cases. The only exceptions are where p = 0.5 and a player's change in performance on game points is opposite to their change in performance on break points. In these situations, there is no impact on the probability of winning the game. When p is greater than 0.5, performing better or worse during break points has a larger impact on the probability of winning the game than equivalent differences in performance during game points. Where players win a minority of points on serve, changes in how they perform during game points have a higher impact on their probability of winning the game than equivalent changes in performance during break points. Table 2 also shows the probability of the serving player winning the game when the probability of winning a point is different during both game and break points to what it is during other points. When p is greater than 0.5, a reduced probability of winning game and break points leads to a greater reduction in the probability of winning the game than the increase in probability of winning the game achieved by equivalent increases in the probabilities of winning game and break points. When the serving player wins a minority of points on serve, however, increased probabilities of winning both game and break points cause a larger increase in the probability of winning a game than the decrease resulting from equivalent decreases in the probability of winning game and break points. When p is greater than 0.5, it is more beneficial to perform better on break points and worse on game points (where the differences to performing on other points are of the same magnitude) than it is to perform better on game points and worse on break points. The opposite is the case where p is less than 0.5.

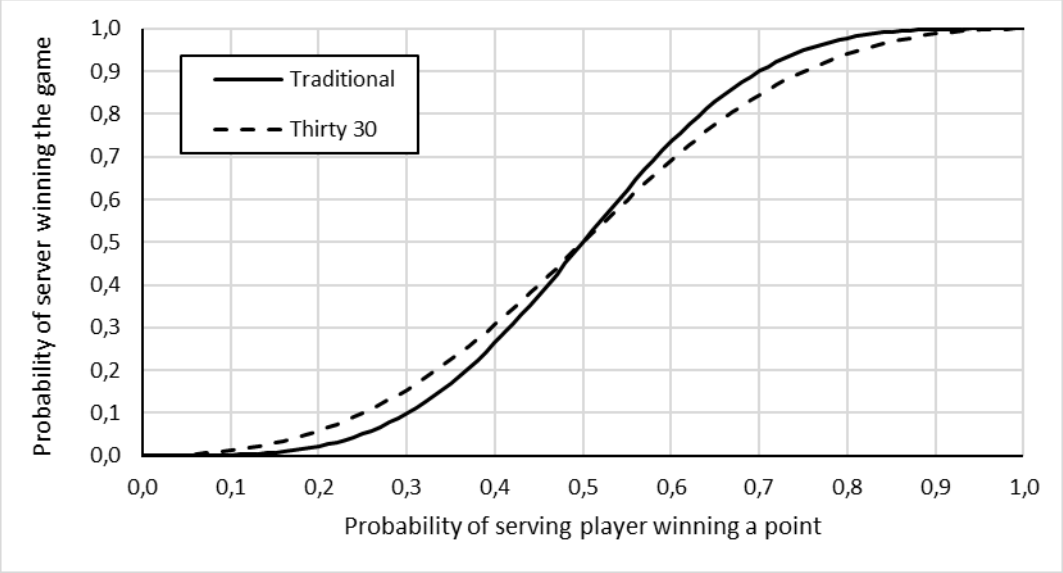

Figure 3. The probability of the serving player winning a game.

Table 1.
Probabilities of players winning points, games, tie-breaks, sets and matches in typical Australian Open singles performances (probabilities are at the start of the given units of play).

Variable	Women's Singles				Men's Singles			
	Winner		Loser		Winner		Loser	
	Traditional	Thirty30	Traditional	Thirty30	Traditional	Thirty30	Traditional	Thirty30
Probability of winning a point on serve, p	0.582	0.582	0.482	0.482	0.662	0.662	0.562	0.562
Probability of winning service game	0.697	0.660	0.455	0.464	0.849	0.793	0.651	0.622
Probability of winning a tie-break when serving first	0.655	0.630	0.345	0.387	0.659	0.654	0.341	0.406
Probability of winning set when serving first (excluding final set)	0.814	0.764	0.186	0.238	0.804	0.759	0.196	0.249
Probability of winning the final set	0.814	0.770	0.186	0.230	0.804	0.765	0.196	0.235
Probability of winning match (best of 3 sets)	0.909	0.860	0.091	0.140	0.900	0.853	0.100	0.147
Probability of winning match (best of 5 sets)	0.952	0.911	0.048	0.089	0.945	0.904	0.055	0.096

Table 2.
Change in the probability of a player holding serve when their probability of winning game or break points is 0.05 higher or lower than when playing any other point on serve.

Difference in probability to p	Version of tennis	The probability of winning points on serve when neither a game point nor a break point (p)										
		0.30	0.35	0.40	0.45	0.50	0.55	0.60	0.65	0.70	0.75	0.80
Game point 0.05 higher	Traditional	0.0119	0.0156	0.0182	0.0192	0.0182	0.0155	0.0118	0.0080	0.0048	0.0025	0.0010
	Thirty30	0.0213	0.0241	0.0256	0.0256	0.0238	0.0207	0.0168	0.0126	0.0088	0.0057	0.0033
Game point 0.05 lower	Traditional	-0.0129	-0.0172	-0.0204	-0.0218	-0.0210	-0.0181	-0.0140	-0.0096	-0.0058	-0.0030	-0.0013
	Thirty30	-0.0223	-0.0256	-0.0276	-0.0278	-0.0262	-0.0230	-0.0187	-0.0142	-0.0099	-0.0063	-0.0036
Break point 0.05 higher	Traditional	0.0059	0.0097	0.0141	0.0182	0.0211	0.0219	0.0205	0.0173	0.0130	0.0086	0.0049
	Thirty30	0.0100	0.0143	0.0188	0.0231	0.0263	0.0279	0.0277	0.0257	0.0224	0.0184	0.0140
Break point 0.05 lower	Traditional	-0.0047	-0.0079	-0.0117	-0.0154	-0.0181	-0.0191	-0.0181	-0.0155	-0.0118	-0.0079	-0.0045
	Thirty30	-0.0087	-0.0125	-0.0167	-0.0206	-0.0237	-0.0255	-0.0255	-0.0240	-0.0212	-0.0175	-0.0135
Game point 0.05 higher & Break point 0.05 higher	Traditional	0.0185	0.0260	0.0329	0.0377	0.0392	0.0370	0.0317	0.0246	0.0172	0.0107	0.0057
	Thirty30	0.0323	0.0394	0.0452	0.0490	0.0500	0.0480	0.0435	0.0373	0.0302	0.0231	0.0166
Game point 0.05 higher & Break point 0.05 lower	Traditional	0.0066	0.0069	0.0059	0.0034	0.0000	-0.0033	-0.0058	-0.0068	-0.0065	-0.005	-0.0032
	Thirty30	0.0115	0.0105	0.0081	0.0044	0.0000	-0.0043	-0.0080	-0.0104	-0.0114	-0.011	-0.0096
Game point 0.05 lower & Break point 0.05 higher	Traditional	-0.0077	-0.0083	-0.0070	-0.0040	0.0000	0.0041	0.0071	0.0084	0.0078	0.0060	0.0039
	Thirty30	-0.0136	-0.0125	-0.0097	-0.0053	0.0000	0.0054	0.0098	0.0126	0.0137	0.0130	0.0112
Game point 0.05 lower & Break point 0.05 lower	Traditional	-0.0171	-0.0245	-0.0316	-0.0369	-0.0391	-0.0376	-0.0328	-0.0259	-0.0184	-0.0115	-0.0061
	Thirty30	-0.0301	-0.0372	-0.0434	-0.0479	-0.0499	-0.0489	-0.0451	-0.0393	-0.0322	-0.0249	-0.0180

DISCUSSION

The results reveal that there is a greater probability of an upset in Thirty30 tennis than in traditional tennis. Upsets can result from Simpson's Paradox (Wright, Rodenberg, and Sackmann, 2013) where a player might win against a higher ranked opponent having won a minority of points in the match. A player can win a five set traditional tennis match by only winning 37% of the points. This is done with a score of 0-6, 0-6, 7-6, 7-6, 7-6 when the player loses all of the opponents serving games to Love, loses their own service games to Love in the first two sets, wins all of their own service games in sets 3, 4 and 5 after the first Deuce, and wins the three tie-breaks 7-5. This gives the player 111 out of 300

points. Simpson's Paradox does not impact on Thirty30 tennis to the same extent because all games with the exceptions of tie-breaks are won by exactly 2 points. A player could win a five set Thirty30 tennis match having won 42.4% of the points. The score would be 0-6, 0-6, 7-6, 7-6, 8-6. The player loses all of their opponent's services games to Love except the last one, loses their own service games to Love in the first 2 sets, wins their own service games to Love in sets 3, 4 and 5, wins the 2 tiebreaks 5-4 and wins their opponent's final service game to Love. This is 50 out of 118 points. Given that Simpson's Paradox is less of an issue in Thirty30 tennis than in traditional tennis, the primary explanation for the greater number of upsets in Thirty30 tennis is due to the games being shorter and hence less representative of player ability. This is consistent with research into other shorter formats of tennis which has found that they also have a higher chance of upsets than traditional tennis (Simmonds and O'Donoghue, 2018; O'Donoghue and Simmonds, 2019). This knowledge may be useful to tournament organisers who need to decide on game formats. Tournament organisers need to balance the chance of top players progressing to the later stages of tournaments with the excitement due to unpredictability of match outcome. The probabilities of superior players winning matches are reduced by a small amount (0.041 in both women's and men's singles). This is expected to result in an additional five upsets in knockout tournaments on 128 players and hence 127 matches.

Serve dominance is reduced in Thirty30 tennis compared to traditional tennis as shown by the lower probability of winning service games for all probabilities of winning a point on serve above 0.5 (Figure 1). Values determined from previous research suggest that 64% of points are won by the serving player on average in professional men's tennis (Gerchak and Kilgour, 2017). This is determined by applying Gale's (1971) equation to the retrospective probabilities of first and second serves being in and the retrospective conditional probabilities of a point being won when these serves are in. The probability of service being held when the probability of winning a point on serve is 0.64 is 0.812 in traditional tennis but reduced to 0.760 in Thirty30 tennis. When p is 0.68 in Figure 1, the difference between holding serve in traditional tennis and Thirty30 tennis is maximised. The probability of serve being held in men's singles matches at Grand Slam tournaments is 0.63 compared to 0.56 for women's singles matches (O'Donoghue, 2013). Therefore, the reduction in serve dominance in Thirty30 tennis would be greater in men's singles at this level than in women's singles. This is especially true on grass courts given that the probability of male players winning points on serve is 0.66 at Wimbledon (O'Donoghue, 2013) which is closer to the 0.68 probability that maximises the difference in holding serve between traditional and Thirty30 tennis. The reduced serve dominance in Thirty30 tennis also has implications for players of different heights. Taller players win more points on serve than shorter players (Söğüt, 2018). However, this translates into a lower probability of holding serve than would be the case in traditional tennis. Therefore, Thirty30 offers a greater chance of success to shorter players.

Games in Thirty30 tennis start at 30-30 meaning that there are more important points in Thirty30 tennis than traditional tennis due to games starting closer to Deuce. These points are also considered more exciting than other points (Pollard, 2002). Morris (1977) defined the importance of a point in a game of tennis as the difference in the probability of winning the game when the point is won and when the point is lost. When the probability of winning a point on serve is 0.6, 30-40 is the most important point (with an importance score of 0.692) with Deuce and 40-30 being among the 9 most important of the 16 points between Love-All and Deuce. The importance of the average point in traditional tennis is not as high due to points such as 40-0 (with an importance of 0.049) not being played in Thirty 30 tennis. Based on Morris's (1977) definition, players encounter more important points in Thirty30 tennis than in traditional tennis. This may present players with a dilemma when using the challenge system during Thirty30 tennis. The importance of the point is a factor that influences whether professional male players use the challenge system (Kovalchik, Sackmann, & Reid, 2017). The greater number of important points in Thirty30 tennis requires players to be especially selective where the importance of the point is one of the factors they are considering when deciding whether to challenge a decision. Break points are clearly more important than game points at higher levels of tennis where the serve is dominant. Players need to be aware of this if using the challenge system in Thirty30 tennis. They should also consider the score in games and sets when deciding to use the challenge system.

If players' performances are affected by the pressure of important points there are implications for fairness based on the order of events (Brams and Ismail, 2018). The player serving first could face break points earlier than the opponent. On the other hand, the player receiving first could face opponent game points earlier. Scoreline effects, such as those experimented with in Table 2, could arise from the performance of the serving player, the receiving player or both players being affected. For example, if the server has a lower probability of saving a break point than winning points where the score is level, this could be due to the performance of the server deteriorating under pressure or the performance of the receiving player being enhanced when there is a break point opportunity. The proportion of break points converted in Grand Slam singles tennis has been found to be greater than the proportion of other points won by the receiver (Knight and O'Donoghue, 2011). Knight and O'Donoghue interpreted this as being due to receiving players not performing as well during points

like 40-0, 40-15 and 30-0 rather than receiving players performing better during break points. The scorelines 40-0, 40-15 and 30-0 do not occur in Thirty30 tennis making a comparison impossible before research is done to analyse actual proportions of points won at the different scorelines. None-the-less, the current theoretical study has shown the impact of scoreline effects on the probability of winning games, with bigger impacts being generated in Thirty30 tennis than in traditional tennis. Professional tennis players with higher mental toughness perform better during critical points than those with lower mental toughness (Cowden, 2016). Therefore, Thirty30 tennis may be a particularly difficult format for those with lower mental toughness. However, Thirty30 matches could be useful to help players cope with critical points as they prepare for traditional tennis matches. The greater exposure to such points offered by Thirty30 tennis can be used by players to develop strategies to minimise the impact of critical points or even enhance performance on such points.

There is also a role for performance analysis support where players win differing proportions of critical points than other points. Match analysis systems are used to record details of points permitting feedback of quantitative and related video sequences to players (Born and Vogt, 2018). Where a player's success within points is found to be scoreline dependent, more in-depth analysis is possible to determine the technical and tactical differences in play between game points, break points and other points. Point types can be classified as aces, double faults, shots per point, net points and baseline points (Fitzpatrick, Stone, Choppin, & Kelley, 2019). Point ending shots can be classified as winners, forced errors and unforced errors (Fitzpatrick et al., 2019), forehand and backhand ground strokes can be distinguished (Delgardo et al., 2019) and whether the point emanated from a first or second serve can be noted (Cui, Gomez, Goncalves, Lui, and Sampaio, 2017). These variables can be contrasted between points played at different scorelines and appropriate feedback given to players and coaches. Decisions relating to play that are based on such feedback can be put into practice during Thirty30 matches. This allows further analysis and feedback before decisions are made about performance during traditional tennis matches.

Starting games at 30-30 reduces the number of points played in matches which can help reduce match congestion. Match congestion is associated with decreased serve accuracy (Maraga, Duffield, Gescheit, Perri, and Reid, 2018), increased pain (Maraga et al., 2018), increased error rates (Gescheit et al., 2016) and fatigue (Fernandez-Fernandez, Sanz-Rivas, and Mendez-Villanueva, 2009). These problems can be addressed by the introduction of shorter formats of tennis such as Thirty30. Service games yield higher physiological demands than receiving games (Mendez-Villanueva, Fernandez-Fernandez, Bishop, Fernandez-Garcia, and Terrados, 2007; Kilit, Senel, Arslan, and Can, 2016). Thirty30 tennis has an additional advantage of reducing the duration of service games and thus further protecting player welfare. Pollard and Noble (2003) have suggested that shorter formats may also reduce injuries in tennis. Thirty30 tennis may, therefore, have a role in reducing injury rates.

In conclusion, Thirty30 tennis matches are shorter than traditional tennis matches, have a higher chance of upsets and reduce serve dominance. A greater proportion of points in Thirty30 tennis are game points and break points than is the case in traditional tennis. This has implications for psychological preparation of players who are competing in this format of the game.

DECLARATION

Mark Milne is the creator of the Thirty30 format of tennis.

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Original Investigation

Scoring bias caused by services in table tennis: a statistical analysis

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Abstract

In table tennis, servers have the potential advantage of scoring bias when serving. However, the length of the scoring bias, i.e. the shot number where any bias is eliminated, has not been clarified. This study aimed to clarify the level and length of scoring bias occurring at services in table tennis. We analysed 45 men's singles matches (3,665 rallies) and 29 women's singles matches (2,352 rallies) from the 2012 London Olympic games and 49 men's singles matches (4,404 rallies) and 31 women's singles matches (2,320 rallies) from the 2016 Rio Olympic games. The statistical analysis revealed that services generate a low scoring phase at the second shot and slightly high scoring phase at the third shot. Moreover, the level of the scoring bias became trivial after the third shot, although a small scoring bias could remain. Players should therefore be cautious of a scoring bias until the third shot. In the gender comparison, the scoring bias observed in matches of male players was larger than that of female players up to the third shot. This result indicates that male players are more likely to take advantage of service than female players. In the winner/loser comparison, it was found that losers use the service to create scoring bias as effectively as winners do. Losers' inferior skills and tactics in the shots after services were the major factor in the difference in the occurrence of missed shots between winners and losers. Finally, we found that the performance of each shot number should be analysed separately up to the third shot, as the remaining effect of the service is remarkably different among shot numbers. The results of this study contribute important suggestions to the conventional methods of performance analysis that empirically separate a rally into three phases.

Keywords: *Table tennis; service; statistical analysis; performance analysis.*

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INTRODUCTION

In table tennis, the service is different from other shots in terms of the rules and conditions under which it is performed. The laws of table tennis stipulate that "the server shall strike the ball so that it touches first his or her court and then touches directly the receiver's court" (The International Table Tennis Federation, 2019, p.36). In addition, the position of the ball is limited in the laws of table tennis; "from the start of service until it is struck, the ball shall be above the level of the playing surface and behind the server's end line, and it shall not be hidden from the receiver" (The International Table Tennis Federation, 2019, p.36). Another key factor is that the service is performed without any interference from the opponent, whereas the other shots are strongly affected by the opponent's previous shot. As stated above, the rules and condition of service are unique compared to the other shots in a rally.

The unique characteristics of service lead to scoring bias in a rally. Using a statistical analysis of 149 matches in the London Olympics 2012, Yoshida, Yamada, Tamaki, Naito, and Kaga (2014) clarified that the scoring rate, i.e. the percentage of scoring shots to total shots, of servers was higher than that of receivers. The criteria of technique effectiveness proposed by Zhang, Lui, Hu, and Liu (2014) also indicates that servers likely use the advantage of service to score a point. In the criteria, higher effectiveness was required to take high evaluation for the first and the third shot than the second and the fourth shot. Tamaki, Yoshida, and Yamada (2017) analysed scoring bias due to service using the scoring rate and losing rate, i.e. the percentage of missed shots to total shots, of each shot number, which is the number of shot starting from the service, (shot number one is the service, shot number two is the return against the service, and so on). They reported that the number of scoring shots was likely to surpass the number of missed shots at the first shot and the third shot. It can therefore be said that servers have a potential advantage to create a scoring bias for themselves using a service in table tennis.

Though scoring bias affected by services has been investigated by researchers, the length of the scoring bias, i.e. the shot number where any bias is eliminated, has not been clarified. Even if a server has good serving skills and gets high scoring rates at the first and third shots, whether the same conditions remain until the fifth shot or after the fifth shot is unknown because the effect of the service may gradually reduce as the number of shots increases. Tamaki et al. (2017) inferred that the effect of the service does not persist for long in a rally because no significant difference was found in a pairwise comparison of the scoring rate and the losing rate among shot numbers after the third shot. This inference, however, did not clarify the length of the bias because no significant difference does not prove no difference. To the best of our knowledge, there are no studies analysing the length of the scoring bias affected by services other than their work. Thus, the length of scoring bias has not been quantitatively analysed, although researchers assumed or noticed that the bias affected by the service gradually decreases.

If the level and length of the scoring bias can be clarified, we can analyse table tennis more accurately and improve players' tactics. Previous studies implicitly assumed that the length of the effect of service significantly reduces in the early phase of a rally. Wu and Li (1992) evaluated the competitive ability of table tennis players using the occurrence rate or scoring tendency in the three phases in a rally: attack after service (scores at the first or third shot), attack after receive (scores at the second or fourth shot), and rally (scores at the fifth or later shots). This three-phase analysis has been widely adopted in match analyses of table tennis (Fuchs et al., 2018). The method assumes that the scoring bias created by the service decreases significantly after the fourth shot; however, there is no evidence to support this assumption in the papers that adopted this method (Hao, Tian, Hao, & Song, 2010; Hsu, 2010; Hsu, Chen, & Wang, 2014; Zhang et al., 2014). If we determined the length of scoring bias affected by the service, the previous method can be revised to analyse table tennis matches more accurately. Knowing the length of scoring bias will also help table tennis players refine their tactics. An effective tactic for a player who is good at service would be to return the player's shot until the level of scoring bias sufficiently decreased. If table tennis players know how many times they have to hit a ball to sufficiently decrease the effect of the service, they can formulate more effective tactics. Thus, the significance of quantifying the length of scoring bias affected by a service is evident from multiple perspectives.

This study therefore aimed to clarify the length of the scoring bias affected by services in table tennis. First, the level of the scoring bias was quantified. The key hypothesis was that the losing rate of a shot would be static after the effect of the service became significantly small. The length of the scoring bias was then estimated according to the change in the level of the scoring bias.

METHOD

Match samples

This study selected 45 men's singles matches (3,665 rallies) and 29 women's singles matches (2,352 rallies) from the matches played at the 2012 London Olympic games and 49 men's singles matches (4,404 rallies) and 31 women's singles matches (2,320 rallies) from the 2016 Rio Olympic games. Defensive players were excluded from the sample. Defensive players were identified by their use of long-pimple rubbers, and primary use of chop. Although a four-year time span can change the characteristics of play, we can analyse the scoring biased affected by the service

commonly observed in 2012-2016 because the service was run under the same rules. The world ranking of the players in the selected matches ranged from 1 to 131, based on the ranking immediately before each Olympic game. The server, winner, and number of the scoring shot were recorded for each rally by observing video recordings broadcasted on television or on the Internet. One unit of the analysis was one player per match. The players were grouped by gender, or match outcome (winners and losers). Written informed consent was unnecessary as the matches were played in public.

Data collection

The server, winner, and scoring shot number were recorded per rally by observing video recordings broadcast on television or on the Internet. Data were recorded by two operators. If different data were found between the two data collected by the two operators, they reviewed the recordings together, making necessary corrections.

Number of shots, missed shots and scoring shots

The number of shots, number of missed shots, and number of scoring shots for each server were computed as per the method proposed by Tamaki et al. (2017). In table tennis, players alternate shots. Thus, we can determine which shot a player hit, if we know the server of the rally and the scoring shot number. Let us assume that player A serves to player B, and that the seventh shot scores. We can determine that player A performed the first, third, fifth, and seventh shot; player B thus performed the other shots in the rally, including the eighth shot. In this study, the number of shots is defined as the number of shot opportunities. Therefore, the next from the scoring shot is always counted as the missed shot, regardless of whether it was performed. In the aforementioned example, the eighth shot is the missed shot. By this method, the number of shots, number of missed shots, and number of scoring shots for each server were computed.

Scoring rate and losing rate of each shot number

We analysed how the services distorted the scoring tendency based on the scoring rate and losing rate. Let '*#i*' be the *i*-th shot, n_i the number of scoring shots at the *i*-th shot, m_i the number of missed shots at the *i*-th shot, and s_i the number of the *i*-th shot. The scoring rate of the *i*-th shot was calculated by n_i/s_i and the losing rate of the *i*-th shot was calculated by m_i/s_i. The sixth and subsequent shots by the receiver were unified into a group denoted by '#6+' and the seventh and subsequent shots from the server were unified into a group denoted by '#7+'. The scoring rate and losing rate were calculated for each player of each match. When s_i is small, the scoring rate and losing rate becomes unstable because of a shortage in the sample size. Therefore, if s_i was less than 10, the scoring rate and losing rate of the *i*-th shot were excluded from the statistical analysis. The threshold of s_i, 10, was empirically determined based on a balance between statistical stability and the sample size for each shot number. Two samples from #4, 17 samples from #5, 19 samples from #6+, and 55 samples from #7+ were excluded, because the number of shots were fewer than 10.

Quantification of the level of scoring bias affected by service

If the scoring bias affected by the service is small, the same losing rate is expected for different shot numbers. The expectation of losing rate L'_j can be calculated using the following equations:

$$L'_j = \sum_{i=j}^{n} m_i / \sum_{i=j}^{n} s_i \quad (1)$$

where *n* is the maximum shot number observed. If the effect of service remains until the *j*-th shot, the observed losing rate becomes farther from L'_j. From another perspective, the distributional distance of the observed losing rate and the expected losing rate can be regarded as the level of scoring bias affected by the service. In this study, the distance between observation and the expected losing rate at the *i*-th shot D_i was estimated by applying Cohen's *w* (Cohen, 1988), a measure of discrepancy between paired proportions. Cohen's *w* can be calculated using the following equation:

$$w = \sqrt{\sum \frac{(p_{1i} - p_{0i})^2}{p_{0i}}} \quad (2)$$

where p_{0i} is a proportion posited by the null hypothesis and p_{1i} is an observed proportion. Sample data are shown in Table 1 and Table 2 to explain how to calculate Cohen's *w*. Table 1 provides a sample of observed losing rate and returning rate, which is a proportion of the shots other than missed shots calculated by $(s_i - m_i)/s_i$, for each shot number. Table 2 provides a sample of the losing rate and returning rate expected from specific ranges of shot numbers. The discrepancy between observed and expected proportions at the second shot D_2 and the third shot D_3 are approximately 0.4 and 0.22, which were calculated by the following equations:

$$D_2 = \left(\frac{(0.08-0.18)^2}{0.18} + \frac{(0.14-0.18)^2}{0.18} + \frac{(0.2-0.18)^2}{0.18} + \frac{(0.23-0.18)^2}{0.18} + \frac{(0.26-0.18)^2}{0.18} + \frac{(0.24-0.18)^2}{0.18} + \frac{(0.92-0.82)^2}{0.82} + \frac{(0.86-0.82)^2}{0.82} + \frac{(0.8-0.82)^2}{0.82} + \frac{(0.77-0.82)^2}{0.82} + \frac{(0.74-0.82)^2}{0.82} + \frac{(0.76-0.82)^2}{0.82} \right)^{\frac{1}{2}} \quad (3)$$

$$D_3 = \left(\frac{(0.14-0.21)^2}{0.21} + \frac{(0.2-0.21)^2}{0.21} + \frac{(0.23-0.21)^2}{0.21} + \frac{(0.26-0.21)^2}{0.21} + \frac{(0.24-0.21)^2}{0.21} + \frac{(0.86-0.79)^2}{0.79} + \frac{(0.8-0.79)^2}{0.79} + \frac{(0.77-0.79)^2}{0.79} + \frac{(0.74-0.79)^2}{0.79} + \frac{(0.76-0.79)^2}{0.79} \right)^{\frac{1}{2}} \quad (4)$$

The expected losing rate depends on the range of shot number used in the calculation; 0.18 is calculated from the second shot and after, and 0.21 is calculated from the third shot and after.

Table 1.
A sample of observed losing rate and returning rate for different shot numbers.

	#2	#3	#4	#5	#6+	#7+
Lossing rate	0.08	0.14	0.20	0.23	0.26	0.24
Returning rate	0.92	0.86	0.80	0.77	0.74	0.76

Table 2.
A sample of the losing rate and returning rate expected from the specific ranges of shot numbers. For instance, '#2–#7+' denotes that the losing rate and returning rate were calculated from the second shot and after.

Range of shot number		#2	#3	#4	#5	#6+	#7+
#2–#7+	Losing rate Returning rate	0.08	0.14	0.20	0.23	0.26	0.24
#3–#7+	Losing rate Returning rate	0.92	0.86	0.80	0.77	0.74	0.76

Cohen (1988) also proposed a general frame of reference for Cohen's *w* as follows:

Small: $w = 0.1$

Medium: $w = 0.3$

Large: $w = 0.5$

According to Cohen's reference, D_2 and D_3 calculated from the sample data shown in Table 1 and Table 2 are regarded as 'between medium and large' and 'between small and medium'. Although Cohen (1998) warned that the magnitude of *w* should be analysed relatively for a particular problem or field, no better basis for evaluating *w* than D_i was available for use in this study. Therefore, we analysed the magnitude of D_i comparatively among shot numbers with reference to the general framework proposed by Cohen.

Statistical analysis

A Kruskal-Wallis test was performed to compare the scoring rate and losing rate for different shot numbers. Wherever significant differences were observed between the shot numbers, a Dunn test with Bonferroni adjustment was used to compare the shot numbers. The effect size *r* between shot numbers was calculated by dividing z-test statistic calculated in Dunn test by the square root of the combined sample size (McCarrol, 2016). The scoring rate, losing rate, and scoring bias were compared between male players and female players and between winners and losers with a 95% confidence interval, calculated by a bootstrap method. Each statistical analysis was tested at a 95% confidence level.

RESULTS

Scoring rate and losing rate by shot number

Fig. 1 shows the distribution of scoring rate and losing rate per shot number and Table 3 shows the effect size between two different shot numbers calculated through the multiple comparisons of scoring rate and losing rate among shot numbers. The scoring rate of shot #1 was significantly lower than those of the other shot numbers. The scoring rate of shot #2 was significantly lower than that of #3, #4, #5, and #6+ in male players' matches; #3, #6+, and #7+ in female players' matches; #3, #4, #5, #6+, and #7+ in winning matches; and #3 and #5 in losing matches. The scoring rate of #3 was significantly higher than #4, #6+, and #7+ in male players' matches; #4, #5, and #7+ in female players' matches; and #3, #4, #5, #6+, and #7+ in winning and losing matches. The losing rate of #1, #2, and #3 were significantly lower than that of the following shot. In the gender comparison, male players' scoring rate was higher than that of female players at shot #5. In winner and loser comparison, winners' scoring rate was higher than that of losers and winners' losing rate was lower than that of winners at all shot numbers except for #1 in losing rate.

Distance from the expected distribution of the shot number of missed shots

Fig. 2 shows the distributional distance between observed losing rate and expected losing rate. As the shot number increased, the distance gradually grew smaller. In the gender comparison, D_2 of female players was lower than that of male players. No significant differences were found in comparison between winners and losers.

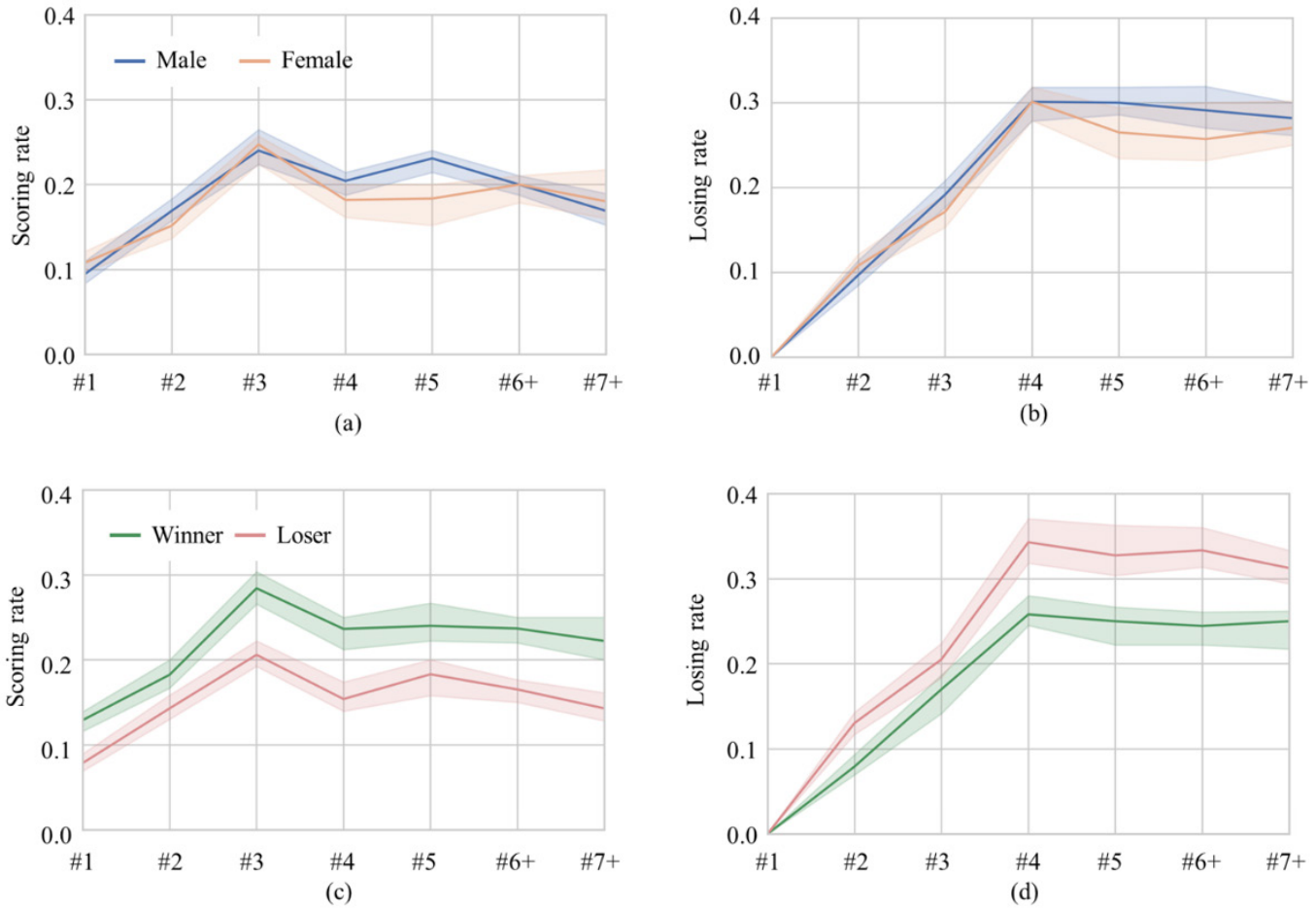

Figure 1. Scoring rate and losing rate at each shot number. The median of scoring rate and losing rate was calculated for each gender, winners, and losers. The shaded area denotes the 95% confidence interval.

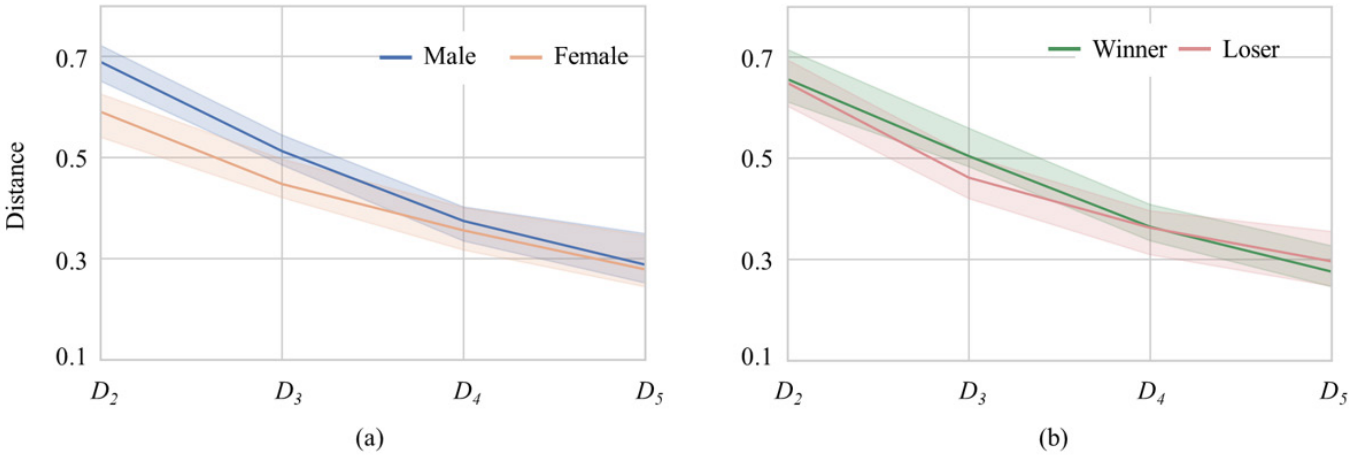

Figure 2. Distances between the observed losing rates and the expected losing rates at each shot number. D_i, the distributional distance at i-th shot, was calculated from the i-th and subsequent shots. The median of the scoring rate and the losing rate was calculated for each gender and for winners and losers. The shaded area denotes the 95% confidence interval.

Table 3.
Effect size between two different shot numbers calculated through the multiple comparisons of scoring rate and losing rate based on shot numbers. The tables show the results for each gender and for winners and losers. The filled colour of each cell denotes the corrected p-value calculated by pairwise comparison as described at the bottom of the table with pink cells denoting that the shot indicated at the left of the table is greater than the shot indicated at the top of the table (denoted as left > top) while the blue cells indicate that the shot at the left of the of the table is less than that at the top of the table (left < top). The effect size in uncoloured cells is not significant.

Scoring rate

		#1	#2	#3	#4	#5	#6+	#7+
Male	#1		-	-	-	-	-	-
	#2	0.34		-	-	-	-	-
	#3	0.72	0.38		-	-	-	-
	#4	0.53	0.19	0.19		-	-	-
	#5	0.63	0.29	0.09	0.10		-	-
	#6+	0.50	0.17	0.22	0.03	0.13		-
	#7+	0.38	0.04	0.33	0.15	0.25	0.12	
Female	#1		-	-	-	-	-	-
	#2	0.21		-	-	-	-	-
	#3	0.69	0.48		-	-	-	-
	#4	0.37	0.16	0.32		-	-	-
	#5	0.36	0.15	0.33	0.01		-	-
	#6+	0.49	0.28	0.20	0.12	0.13		-
	#7+	0.42	0.21	0.27	0.05	0.06	0.07	
Winner	#1		-	-	-	-	-	-
	#2	0.28		-	-	-	-	-
	#3	0.80	0.52		-	-	-	-
	#4	0.57	0.29	0.23		-	-	-
	#5	0.62	0.34	0.18	0.04		-	-
	#6+	0.61	0.33	0.19	0.04	0.01		-
	#7+	0.51	0.23	0.28	0.06	0.10	0.09	
Loser	#1		-	-	-	-	-	-
	#2	0.36		-	-	-	-	-
	#3	0.77	0.41		-	-	-	-
	#4	0.46	0.10	0.31		-	-	-
	#5	0.55	0.20	0.21	0.09		-	-
	#6+	0.48	0.12	0.29	0.02	0.08		-
	#7+	0.39	0.04	0.37	0.07	0.16	0.08	

Losing rate

		#1	#2	#3	#4	#5	#6+	#7+
Male	#1		-	-	-	-	-	-
	#2	0.35		-	-	-	-	-
	#3	0.65	0.31		-	-	-	-
	#4	1.06	0.71	0.41		-	-	-
	#5	1.05	0.71	0.40	0.01		-	-
	#6+	1.04	0.69	0.39	0.02	0.01		-
	#7+	0.98	0.63	0.33	0.08	0.07	0.06	
Female	#1		-	-	-	-	-	-
	#2	0.41		-	-	-	-	-
	#3	0.64	0.22		-	-	-	-
	#4	1.10	0.69	0.47		-	-	-
	#5	0.97	0.55	0.33	0.13		-	-
	#6+	1.00	0.59	0.36	0.10	0.03		-
	#7+	1.02	0.61	0.39	0.08	0.06	0.02	
Winner	#1		-	-	-	-	-	-
	#2	0.36		-	-	-	-	-
	#3	0.67	0.32		-	-	-	-
	#4	1.08	0.72	0.41		-	-	-
	#5	1.00	0.64	0.33	0.08		-	-
	#6+	1.01	0.65	0.34	0.07	0.01		-
	#7+	0.97	0.61	0.30	0.10	0.03	0.03	
Loser	#1		-	-	-	-	-	-
	#2	0.36		-	-	-	-	-
	#3	0.61	0.25		-	-	-	-
	#4	1.10	0.73	0.48		-	-	-
	#5	1.04	0.68	0.43	0.06		-	-
	#6+	1.06	0.69	0.44	0.04	0.02		-
	#7+	1.02	0.66	0.41	0.08	0.02	0.04	

left > top: $p < 0.01$ $p < 0.05$ left < top: $p < 0.01$ $p < 0.05$

DISCUSSION

Scoring bias affected by service

Service was found to lower the scoring rate and losing rate of shot #2, lower the losing rate and increase the scoring rate compared to other shots. It is possible that the low losing rate on shot #2 could be due to the difficulty in scoring from #1, which is, in turn, due to the laws of table tennis as mentioned in the introduction. The low scoring rate of #2 cannot be described by the low scoring rate or low losing rate of #1. The low scoring rate of #1 and high scoring rate of #2 could be co-occurring; moreover, the tactics of servers may affect the scoring rate of #2. Considering the difficulty in scoring at service, servers may make it difficult for receivers to score on their return, which may be achieved by skilfully leading opponents to incorrect identification of the spin or placement of a service (Geske & Mueller, 2010, pp.71-77). As the receiver is required to penetrate such deception by the server, the scoring rate of #2 was commonly lower than that of the following shots. The low losing rate of #3 could be the result of the low scoring rate of #2. The high scoring rate of #3, however, does not result from the low scoring rate or low losing rate of #2. As with the low scoring rate of #2, the high scoring rate of #3 could be due to the servers' skills, such as intentionally misleading opponents in their identification of the spin and the placement of service. In terms of effect size, however, the difference was relatively small, particularly in female players and winners. We can therefore conclude that the service was mainly found to generate a low scoring phase at shot #2 and relatively small effect at #3 as the server's scoring bias.

How does the level of scoring bias change with each shot?

It was found that the level of scoring bias became insignificant from shot #4, although a slight scoring bias could remain. According to Fig. 2, scoring bias decreased drastically with each shot. Moreover, Table 3 shows that the effect size was remarkably small in the comparison of scoring rate and losing rate among all shots after #3. These results indicate that the scoring rate became smaller every time a shot was performed. According to Cohen's reference, however, D_4 and D_5 can be interpreted as medium. Although we should avoid placing too much importance on Cohen's criteria, the observed distance indicates that a certain level of scoring bias could remain, even at shot #4 and at subsequent shots. However, the scoring bias would be too trivial to consider if its effect on scoring rate and losing rate became small. According to the effect size of scoring rate and losing rate between shot numbers (Table 3), we can estimate that the level of the remaining scoring bias would be small for the shots after #3. We should therefore be cautious of scoring bias after #3 only if we know that the latter phase of a rally is important for the analysis of matches.

Quantifying the level of scoring bias affected by service was a notable achievement of the current study. In the results of their pair-wise comparison of losing rate, Tamaki et al. (2017) implied that the effect of service became small after #3 because there were no significant differences among shot numbers after shot #3. However, the absence of significant difference does not imply no difference at all. Moreover, they could not determine whether a small scoring bias would remain after #3 because the level of scoring bias was not quantified. In the current study, the level of scoring bias was calculated based on the distributional distance from the expected losing rate, which allowed us to understand the changes in scoring bias at each shot.

Gender comparison

The level of scoring bias in the early phase of a rally differed between genders. In the male players' matches, the impact of service was greater than that in female

players' matches. From this result, we can hypothesise that male players are more likely to take advantage of service than female players. However, the difference between genders reduced at every shot and became little or none from shot #4. These results suggest that the level of scoring bias is different between genders particularly up to #3. These results also suggest that the level of scoring bias is not strongly related to its sustainability. Even if some servers have good serving skills, the length of scoring bias would be virtually the same as the common length.

Winner and loser comparison

Identical scoring bias was observed in winning and losing matches, whereas the scoring rate and losing rate were evidently different. When comparing the scoring rate and the losing rate between the winners and losers, the winners seem to use the service more effectively than the losers. However, no difference in scoring bias was found between the winners and losers. Let us compare the main effect of service — specifically, lowering the scoring rate at #2— between winners and losers. The average effect size between #2 and at each shot after #2 of winners was 0.34(±0.11) and that of losers was 0.17(±0.14). As winners' shot #2 was affected by losers' services, the results may indicate that losers service lowered the scoring rate at shot #2 more than winners' service did. However, it should be noted that winners' scoring rate of shots after the #2 was significantly higher than that of losers. It is also possible that winners' superior skills or tactics at the shots after #3 increased the difference between scoring rate at #2 and that of other shots. Although this cannot simply be concluded that from the results, it can be said that losers' service evidently biased the scoring tendency at least as much as the winners' service did. Next, we discuss the difference in the shots after the service. Because the scoring bias has been reduced in the shots after #3, the difference in the losing rate after #3 can be a measure of differences in tactics or hitting skills at the shots after the service. The confidence interval of losing rate after #3 was [0.24, 0.26] in winning matches, and [0.33, 0.35] in losing matches. A rough calculation shows the difference between the two intervals to be 0.09. The losers' inferior skills and tactics at the shots after the service increases the differences on the losing rate at all shots after the service between winners and losers. Therefore, losers use the service effectively and create a certain level of scoring bias in a rally at least as well as winners do; however, the scoring rate is low and losing rate is high because of the poor performance of the shots after the service.

Suggestions for the methods of performance analysis

Based on our results, we suggest that the performance of table tennis players should be analysed according to each separate shot number, particularly up to #4. The method proposed by Wu and Li (1992), which has been widely adopted in table tennis, separates a rally into the following three phases: shots #1 and #3, shots #2 and #4, and shots after #4. This analysis method is reasonable for analysing players' total performance of serving skill or returning skill; however, the performance analysis would be more accurate if we separate #1 and #3 and #2 and #4. This is because the remaining level of scoring bias is remarkably different among shot numbers up to #4. Furthermore, unifying the shots after #4 was validated to be reasonable in most cases in real life scenarios. However, we should consider separating the shots after #4 if we know important features that exist in the latter phase of a rally.

Limitations of this study

The findings of this study should be considered along with its limitations. As this study focused on the average effect of the service in table tennis, the scoring bias affected by the shots after the service were analysed separately. In the rally of table tennis, however, every shot may change the scoring tendency and create the scoring bias. It should be noted that the findings of this study are approximations calculated under the ideal hypothesis that the losing rate of a shot is static after the effect of the service became significantly small. Moreover, the scoring bias affected by service may change over time. In this study, the period of time we selected the matches from was 2012 to 2016. As the techniques and tactics of table tennis are constantly changing, the bias in scoring by service will not necessarily be the same in the future. It is necessary to study the scoring bias affected by service at regular intervals in order to accurately analyse table tennis matches and construct effective tactics. In addition, it should be noted that it is very difficult to analyse the variation in the effect of services at the shots after #5 through this research methodology. Since offensive styles have become dominant in modern table tennis, scores are often decided early in a rally. Therefore, it is hard to collect enough information on the long-lasting phase of a rally. Although we clarified that a slight scoring bias could remain even after shots #4, the variation of the effect of services after the shots after #4 could not be mentioned.

CONCLUSION

This study investigated the level and length of scoring bias affected by service in table tennis. We found that services generate a low scoring phase at the second shot and slightly high scoring phase at the third shot. Moreover, the level of scoring bias was revealed to become trivial at all shots after the third shot, although a slight scoring bias could remain. The scoring rate was estimated from the distributional distance between the observed losing rate of each shot number and the estimated losing rate. The differences in scoring bias between male players and

female players and between winners and losers were also observed. In the gender comparison, the scoring bias observed in male players' matches was larger than that observed in female players' matches up to the third shot. In the winner and loser comparison, it was found that losers also use service effectively and create a certain level of scoring bias as much as winners do. Finally, we suggested that the performance of each shot number should be analysed separately up to the third shot.

DISCLOSURE STATEMENT

The authors report no conflicts of interest

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Original Investigation

Consumption habits and economic impact of Liebherr 2019 ITTF World Table Tennis Championships

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Abstract

Organising international sports events became one of the most important elements of the prioritized sports sector in Hungary. The main goal of this study was to examine the economic impact of Liebherr 2019 ITTF World Table Tennis Championships (WTTC) for the Hungarian GDP. The impact is based on consumption habits of stakeholders and total budget of organisers so it was necessary to analyse the characteristics of passive sports tourists and all other stakeholders and their spending too. Consumption of stakeholders were surveyed with questionnaire (n=1097) and the budget of the organisers were presented by the Hungarian Table Tennis Association. We have used the secondary data of Hungarian Statistical Office and Eurostat for input-output modelling. Expenditures and spending behaviour of stakeholders were calculated by inferential statistics, differences were tested by independent-samples T tests, ANOVA and Chi-square tests. Input-output modelling method was used for estimating the direct and indirect macroeconomic impacts. Daily spending of domestic (47.9 EUR/day) and foreign (102.8 EUR/day) passive sports tourists coming to the WTTC were calculated. Foreign passive sports tourists spent an average 3.85 days in the country. Examining the macroeconomic effects it can be stated that every EUR of government support increased the country's GDP by 1.21 EUR and generated a tax of 1.01 EUR in 2019. Expenditures of spectators and participants contributed 24% of the generated GDP. Passive sports tourists of WTTC spent more money than the general domestic and foreign tourists (20.6 EUR/day and 51.8 EUR/day respectively) or even the domestic or foreign sports tourists (24.7 EUR/day and 54.7 EUR/day respectively). They spent more time than general foreign tourists or foreign sports tourists as well (2.26 days and 2.29 days respectively) in Hungary. The Hungarian government provided almost 4 million euros support to the organisers and this amount is exceeded by the total contribution of WTTC to the Hungarian GDP (4.7 million EUR).

Keywords: *World Table Tennis Championships, consumption habits, economic impact, input-output model*

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INTRODUCTION

Tourism areas for sports and physical activity have been constantly growing since the turn of the millennium. Tourism and economic professionals predict a dynamic expansion in active and passive sports tourism for the next decade (Dreyer, 2002; Bánhidi, 2015; Borbély & Müller, 2015). Sports events tourism is one of the highlights of sports tourism and it has been growing significantly in recent decades. Sports events and especially international sports events are nowadays characterized by fast paced evolution. Organisers focus on intangible values i.e. experience and entertainment (sometimes even at the expense on sport's professional aspects), which generate the emergence of new competition series and forms (e.g. new multisport events such as the European Games or the new World Table Tennis Series). At the same time, the number of viewers of worldwide sports events and the amount of its revenues are growing, and we can clearly see the trend of globalisation regarding the international sports events (Stocker, 2013; Bánhidi, 2018; Laflin, 2018; Laczkó & Stocker, 2020).

One of the characteristics of sports events tourism is that they have two main target groups that differ in their motivation and characteristics. The first is the participants' group (such as athletes, delegates, organisers, etc.) whose travels are classified as professional tourism based on their characteristics and motivations, while the second is the spectators' group (local, domestic and foreign spectators) whose touristic consumption is interpreted as a part of leisure tourism (Standeven & De Knopp, 1999; Lasztovicza & Béki, 2016). The size of the global spectators' market and its rapid expansion have placed the study of spectators' characteristics and consumption habits into the focus of international sports and economics researches (Bánhidi, 2018). Based on this research, it can be said that nowadays spectators attend sports events primarily to gain experiences and let themselves to be entertained, therefore, they are looking for non-sports related attractions and services, and can be characterized by increased demands for these attractions compared to the average tourist (Albers, 2004; Chen & Funk, 2010; Stocker & Laczkó, 2020).

Although the main focus of the Hungarian tourism is not sports tourism, it can be said that more and more attention has been paid to the development of sports-related tourism trends in recent years (Sulyok & Magyar, 2014; Hungarian Tourist Agency, 2017). The expansion in the sector is explained and supported by several social and economic trends as well as government decisions. Among the social trends, the rising participation rate of the Hungarian population in recreational sports for health purposes and the increasing sports consumption must be highlighted (Kovács, Paár, Elbert, Welker, Stocker, & Ács, 2015; European Commission, 2018). An important driver of the development of Hungarian sports tourism is the government's decision to handle sport as a strategic sector since 2010, as well as the fact that the area also appears as a priority in tourism development strategies at various levels. Organising international sports events became one of the most important elements of the prioritised sports sector (Stocker & Szabó, 2017) and its over-spilling effects are in focus of scientific researches nowadays (Laczkó & Paár, 2018; Paár & Laczkó, 2018). As a result the number of international sports events applied for and held in the country increased significantly from 2010 and also included events with higher prestige and professional quality. More than 120 international sports competitions were held in Hungary in 2019. The Formula One race, the World Table Tennis Championships (WTTC), the Canoe Sprint World Championships, the Fencing World Championships and the Modern Pentathlon World Championships were held among others this year. According to the data of Sportcal Global Communications, Budapest was the 3rd, while Hungary was the 18th in the world ranking of settlements and countries organising international sports events in 2019 (Sportcal Global Communications, 2019a).

Hungary has a very successful past in the sport of table tennis and the Hungarian Table Tennis Association has considerable experience in organising international sports competitions. Hungary is the second most successful table tennis nation with 202 medals at the World Table Tennis Championships. These results came from a series of successes between the two world wars and the 1950s and 1970s. Hungary has paid special attention to the application and organisation of international table tennis competitions in the recent years. In addition to the annual World Tour series in the country, the European Championships (EC) was held in 2016, while the individual WTTC was held in April 2019 and the European Veteran Championships (EVC) was held one month later. Budapest hosted the WTTC for the fourth time in its history in 2019 (after 1929, 1931 and 1950). Budapest is the second placed settlement in the world after London regarding the number of organised World Table Tennis Championships. Budapest wanted to become the centre of international table tennis life with these events in 2019.

The main research question of this paper is the economic impact of the Liebherr 2019 ITTF World Table Tennis Championships. This total impact can only be calculated including the consumer habits of different stakeholders of the event, therefore the consumer habits will be demonstrated first, then the economic impact calculations will come.

The hypothesis of the study is that the Liebherr 2019 ITTF World Table Tennis Championships contributed more to the Gross Domestic Product of Hungary than the subsidy it got from the government.

MATERIALS AND METHODOLOGY

Information about the consumer behaviour of spectators and participants was obtained by the survey methodology and information about the budget of the event was provided by the local organising committee.

Design & Procedures

We created slightly different questionnaires for different stakeholder groups in international sports events to obtain primary research data, and we selected the sample with quota sampling. Interviewers were sent to the event and they recorded the answers of the spectators. The questionnaires were created with different types of questions: open-ended questions (some financial and some textual), closed-ended questions and Likert-scale questions about the basic statistical data of the respondents, the different types of expenditures spent and their amounts, the length of stay, the different tourist appeals, the quality of the event organisation, the willingness to return to the country and the attitude about how spectators rated Hungarian people's hospitality.

Further primary research data was provided by the local organising committee about the budget of the events and the numbers of different participants. According to secondary sources, we used public data from the national sports associations, the Hungarian Central Statistical Office (HCSO), the Statistical Office of the European Union (Eurostat) and other sports professional fora. The gathered primary and secondary data were used as inputs for the input-output modelling.

Expenditures and spending behaviour of spectators, travel and other tourist behaviour were calculated by the primary data with inferential statistics.

The differences of the given variables were calculated with independent-sample T tests, ANOVA tests and Chi-square tests depending on the operationalization of the given variable. The significance level was set at $p < 0.05$ (Ács, 2007; Ács, 2014).

Participants

Our interviewers recorded 1139 survey entries from the spectators' and the participants' questionnaires together at the Liebherr 2019 ITTF World Table Tennis Championships. We had to exclude 42 entries because of interviewer data entry problems or because of the unfinished status of the questionnaires. The final sample consists of n=1,097 survey entries from which n=355 are from domestic spectators, n=641 are from foreign spectators and n=281 are from professionals (athletes and sports professionals) as it can be seen in table 1. Altogether n=1,097 person was included in the sample from the participating 11.5 thousand which means 9.5% sample rate.

Table 1.
Sample sizes and number of participants at Liebherr 2019 ITTF World Table Tennis Championships (Budapest, HU)

	Domestic spectators	Foreign spectators	Professionals	Total
Sample size (n)	355	461	281	1,097
Participants (N)	5,577	3,810	2,199	11,586
Proportion (%)	6.4%	12.1%	12.8%	9.5%

Sources: Authors' compilation

Analysis

The direct and indirect impacts of the World Championships were calculated by the economic input-output modelling method, which is widely used by impact calculation studies in event tourism (European Commission, 2012; Kóródi, 2011; Kundi, 2012; KPMG, 2015; Laczkó-Stocker, 2018; Stocker-Laczkó, 2020).

Economic impact is mostly connected to the organisation of the event and the consumption of the participants as the consumption of the spectators is usually responsible for a smaller amount in table tennis.

The economic impact of the international sports event was calculated from the direct expenditure of the event and its participants and the indirect impact they caused in the national economy. From the spectators' expenditure the expenditure of entry tickets was ignored as these were included in the budget of organisers. Travel costs of foreign spectators were also excluded as these occur usually in their home country which means it does not have impact in the Hungarian economy. Those spectators' expenditures were excluded from the impact analysis who reported that their primary travel reason was different than the World Championships, as their economic impact should have been calculated in the impact analysis of the primary reason of travel. According to Hungarian spectators related calculations in the impact analysis we decreased the number of Hungarian spectators with 1.7% as their primary motivation was not the WTTC and we also decreased the expenditures of the remaining Hungarian spectators by 16.7% as they would have been spent money in Hungary if the WTTC would not take place in the country. Exact measures are the benchmarks taken from another Olympic sport's World Championships in Hungary in 2019.

Financial contribution of sponsors was included in the budget of the organisers. Non-financial sponsorships were included in the research too. These were products, services and sporting goods. Sponsors also contributed to the event with letting their employees work in the event, their fair value was also included in the research.

As the organisation of the event also included imported goods but these imported goods created value for their home economy, therefore they were excluded from the calculations.

The created input-output model used the previously described data. We used multipliers obtained from the input-output analysis of Hungarian sectors to estimate the indirect impact as well (Stocker & Boda, 2018). The different expenditures spent in accordance with the World Championships were spent in the following sectors: sports activities and amusement and recreation activities; accommodation and food service activities; transportation and storage; manufacture of food products, beverages; manufacture of wearing apparel; human health activities; services to buildings and landscape activities; and education. Sectoral multipliers were used for the expenditure to the respective sectors and we could estimate the impact of foreign spectators' expenditures on the Hungarian GDP with these calculated multiplier effects.

All statistical calculations were made by IBM SPSS Statistics 25 and Microsoft Excel (from Microsoft Office 365 ProPlus).

RESULTS

Consumption and touristic characteristics of the WTTC

The characteristics and opinions of domestic spectators are based on a sample of 355 people, which is 6.4% of the Hungarian spectators.

A total of 75.2% of Hungarian spectators were men, 24.8% were women at the WTTC in 2019. In terms of age distribution 22.0% were under 20 years of age, 14.4% were 20-29 years of age, 10.7% were 30-39 years of age, 24.8% were 40-49 years of age, 16.1% were 51-60 years of age and 12.0% were over 60 years.

A total of 30.7% of the respondents came from Budapest to the competition. 18.5% of domestic spectators travelled for up to 1 hour and a further 25.1% travelled between 1 and 2 hours to watch the competition in addition to the this. 25.7% of the domestic spectators came from a distance of more than 2 hours. It can be said that more than half of the domestic spectators (50.8%) travelled at least 1 hour to watch the competition. Domestic spectators came to the WTTC from all counties of the country.

According to modes of travel 71.2% of the spectators arrived by car (or minibus), 18.6% by public transport, 8.8% by train/coach, and 1.4% used other vehicles (such as bicycles etc.).

More than a third of the respondents (33.8%) watched the competition with their families, 22.1% of them came alone, 19.8% came with friends and acquaintances, while 24.3% came with sports mates.

The Hungarian spectators watched an average of 2.56 (SD = 2.15) competition days.

According to accommodation 20.0% of the spectators booked accommodation related to the competition and they spent an average of 3.18 (SD = 2.56) nights. Taking all domestic viewers into account, they spent an average of 0.64 (SD = 1.71) guest nights in and around Budapest. This meant a total of 3,569 guest nights in the capital during the competition period. Most of the used accommodations were cheaper ones, such as sleeping with friends or lower-rated commercial accommodations. Only 38.0% of those who spent guest nights related to the event slept in 3-stars or higher rated hotels (12.7% in 4-stars hotels and 25.3% in 3-stars hotels), while 40.1% of them slept by friends and acquaintances and 19.7% of them spent their nights in rented apartments or other non-commercial accommodation.

Figure 1 shows the distribution of Hungarian spectators' expenditure. Domestic spectators spent an average of 47.9 EUR (SD = 49.5) per day of the competition. This amount is significantly higher than the average 20.6 EUR (t = 10.4, p = 0.000) daily spending by the average Hungarian tourists on multi-day trips in Hungary in 2019 and the average spending of 24.7 EUR on cultural and sports events (t = 8.8, p = 0.000) (HCSO, 2020).

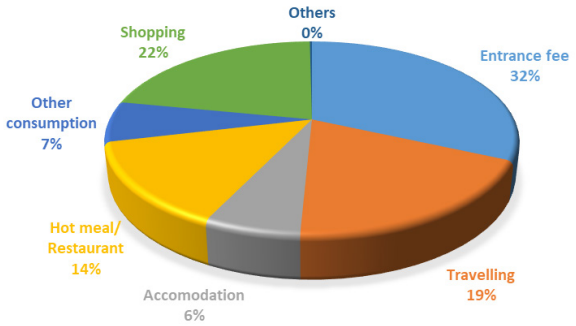

Figure 1. Distribution of Hungarian Spectators' Expenditure (%)

Domestic spectators rated the entertainment value of the competition as good, as 62.5% of the respondents rated the WTTC as five on a scale of 1 to 5. The mean of the ratings was 4.48 (SD = 0.87). Only 5.9% of the respondents rated the entertainment value of the competition as 3 or lower. The followings were considered important among the entertaining elements of the competition: the players' playing level, the quality of the matches (4.71, SD = 0.07), the information announcements (4.44, SD = 0.09), the work of the organising staff (4.41, SD = 0.09) and the presence of domestic players (4.26, SD = 0.1). The presence of show elements (3.46, SD = 0.14) and the competition's unpredictability factor (3.89, SD = 0.15) were considered significantly less important.

The quality of the competition's organisation was rated as slightly weaker, averaging 4.30 (SD = 1.11).

The characteristics and the opinions of the foreign spectators are based on a sample of 461 people, which is 12.1% of the foreign spectators.

A total of 75.1% of foreign spectators were men and 24.9% were women. In terms of age distribution 8.1% were under 20 years of age, 26.5% were 20-29 years of age, 21.0% were 30-39 years of age, 22.1% were 40-49

years of age, 13.8% were 51-60 years of age and 8.5% were over 60 years (see Figure 2).

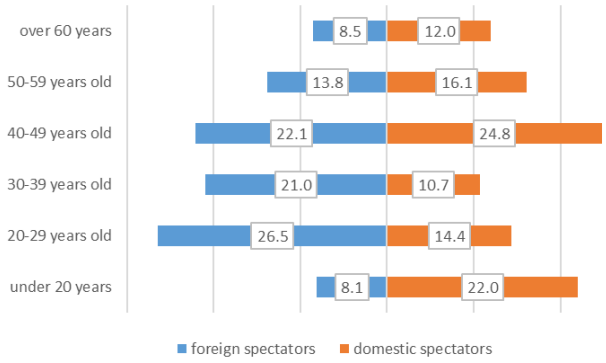

Figure 2. Age Distribution of Domestic and Foreign Spectators at the WTTC

The sample included citizens of 34 countries. 14.1% of respondents came from Asia (China, Japan, India, Kazakhstan, Lebanon, Philippines), 0.4% came from the Americas (USA, Brazil) while the vast majority came from European countries (85.5%). Most Europeans came from Germany (24.7%), Slovakia (17.1%), Romania (6.1%), Sweden (5.4%) and England (4.3%).

More than a third (34.7%) of foreign spectators arrived by road by their own car (or minibus) and a significant number of them also arrived by plane (45.4%) to Hungary. Due to the favourable geographical location of Budapest, a significant number of foreign spectators also arrived by train (19.2%).

The foreign spectators of the WTTC spent an average of 3.85 nights (SD = 2.08) in Hungary. 53.7% of them spent their nights in at least 3-stars hotels (38.4% in 4- and 5-stars hotels), while 35.4% slept in rented apartments. Foreign spectators spent a total of 13,488 nights related to the WTTC.

Foreign spectators spent an average of 102.8 EUR (SD = 64.3) per day without travel costs during the competition, while this amount was 128.2 EUR (SD = 95.2) per day if travel costs were included. This meant an average of 624 EUR (SD = 645) including travel costs for the entire stay in Budapest. The daily spending of foreign spectators of the WTTC was significantly higher than the general foreign tourists' 51.8 EUR/day (t = 17.0, p = 0.000) and the average spending of tourists arriving especially at sports events which was 54.7 EUR/day (t = 16.0; p = 0.000) in Hungary in 2019 (HCSO, 2020). Distribution of foreign spectators' expenditure can be seen in Figure 3.

Foreign spectators rated the quality of the WTTC as favourable, as more than four-fifths (85.1%) of the respondents rated the organisation of the competition as at least four. 11.4%, of them rated it as three, and only a very small number (3.5%) gave a less favourable rating. The **average rating** of the foreign spectators was **4.26** (SD = 0.80).

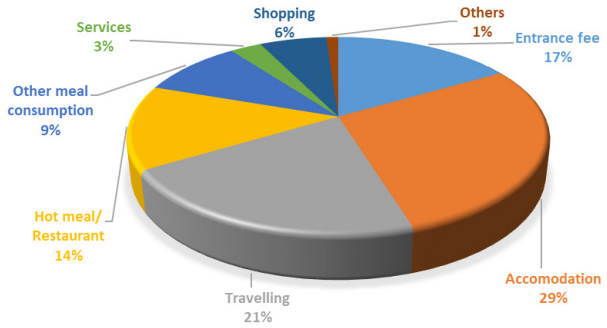

Figure 3. Distribution of foreign spectators' expenditure (%)

Examining the tourism related consumption of foreign spectators, it can be said that almost two thirds of the respondents (61.0%) were curious about the tourist attractions of Budapest and its surroundings. Several tourist destinations were visited by 37.2% of foreign spectators on several occasions in addition to the WTTC. Foreign spectators viewed mostly the main tourist attractions of Budapest similarly like general tourists. The city centre (Parliament, Danube riverbank) and the UNESCO World Heritage's sites (Buda Castle, Heroes' Square, Andrassy Street) were visited by 88.3% of the foreign spectators, while 10% of foreign spectators were looking for entertainment opportunities, but cultural (1%) and shopping tourism (0.4%) motives were negligible. Only 2% of spectators were involved in programs organised by tourism providers.

Foreigners rated the hospitality of Hungarians averagely at 4.6 (SD = 0.61) based on the experiences of their trip to Hungary related to the WTTC.

The vast majority of foreign spectators would like to return into Hungary in the future. More than half of them (57.7%) would like to return within 5 years based on their previous experiences, while the proportion of those who refuse to return is only 3.5%.

There is a significant relationship between the perception of hospitality and the willingness to return (χ^2 = 37.19; p = 0.000). It can be said that those who rated hospitality more positively plan to return to Budapest in the future (64% of those who rated hospitality as 5 plan to return to Budapest within 5 years).

The willingness to return was also significantly influenced by the assessment of the organisation of the competition (χ^2 = 28.9; p = 0.004). Those who considered the quality of the organisation to be more favourable would return to the Hungarian capital in a larger proportion in the future. Almost two-thirds (63.4%) of the foreign spectators who rated the organisation as the best possible (as 5) would like to return in the next 5 years.

The characteristics and the opinions of the professional participants are based on a sample of 281 people, which is 12.8% of the professional participants.

Foreign participants came to Budapest from 99 countries of all five continents. The foreign participants spent an average of 6.0 (SD = 2.1) and a total of 13,003 guest nights in the event's 9 official hotels (two 3-stars, five 4-stars and one 5-stars) in Budapest.

82% of the participants arrived into the Hungarian capital by plane, while 16% arrived by road (car, minibus).

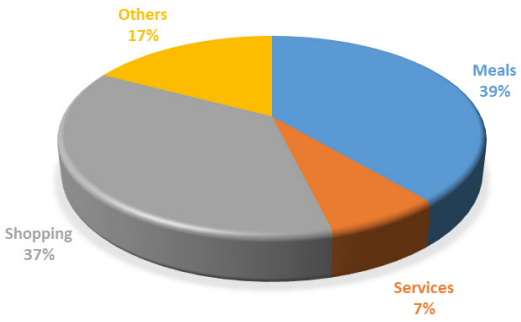

Figure 4. Distribution of the participants' local expenditure (%)

The hospitality of the participants (in terms of accommodation, meals and transfers) was part of the accreditation, so we wanted to know more about their additional expenses. The participants spent an average of 265.3 EUR (SD = 386.1) during their stay in Budapest, which was 44.9 EUR (SD = 65.3) per day in addition to their basic hospitality. Players spent significantly the least (29.2 EUR/day; SD = 37.7), while other participants (ITTF members, media professionals, umpires and referees, technical staff) spent the most (61.6 EUR/day; SD = 87.4) among participants (coaches and delegates spent 44.1 EUR/day; SD = 39.1) ($p = 0.034$). The overall structure of their spending is shown by Figure 4.

The quality of organisation was rated averagely 4.24 (SD = 0.85) by the participants.

A total of 47% of the participants visited the city centre because of non-competitive motivations in addition to their duties related to the sports event. The range of tourist attractions visited was almost exclusively concentrated in the downtown and World Heritage sites (96.9%), only 2% visited spas and other activities.

The hospitality of the Hungarians was judged by the participants very favourably similarly to the foreign spectators, averaging 4.6 (SD = 0.69). The willingness to return among the participants was also reported very similarly as by the spectators (although probably with different goals) at the same time, 55% of foreign participants plan to return to Budapest within 5 years, while only 2.6% do not want to come to Hungary again.

Economic impact analysis of the 2019 World Table Tennis Championships

Direct expenditure related to the 2019 World Table Tennis Championships was 7.15 EUR million as it can be seen in table 2.

Table 2.
Net direct expenditure by stakeholders in LIEBHERR 2019 WTTC (EUR)

Organisers	Sponsors	Extra expenditure of Participants	Foreign spectators	Domestic spectators	Total
5,106,235 EUR	59,090 EUR	461,854 EUR	1,259,134 EUR	264,742 EUR	7,151,055 EUR

Source: Authors' compilation

Direct revenue to the central budget from the WTTC was 2.32 million EUR, which consists of VAT, employee related taxes and insurance. Local government will get tourist tax and local business tax and indirect tax revenues which are also created by the multiplying effect of the demand of WTTC.

Average import ratio of the segments from where the WTTC procured products and services is 4%, therefore the demand side of the organisation and the other stakeholders expenditure had to be decreased by this amount in the economic impact analysis. Estimated import of the event was 294 thousand EUR, therefore direct national impact of WTTC was 6.86 million EUR.

For the suppliers be able to deliver products and services indirect products and services were needed, therefore the given segments' economic multiplier effect had to be taken into account. According to the structure of the expenditure the **weighted average multiplier** became **1.71**, which means that the 7.15 million EUR demand of the WTTC needed 11.75 million EUR output from the Hungarian supply chain, which means the WTTC generated 11.75 million EUR output in the Hungarian economy.

The weighted average added value multiplier of the segments of the expenditure structure of WTTC is 0.36, which means that WTTC generated 4.28 million EUR added value in the Hungarian economy.

Other taxes can be also calculated from input-output analysis, the weighted average multiplier of the respective economic segments was 0.04, which means other taxes generated by WTTC were 502 thousand EUR. WTTC created 4.78 million EUR GDP contribution altogether.

Income taxes and social security paid to the central budget from the generated GDP of WTTC was 1.12 million EUR on top of what 2.9 million EUR VAT was also paid into the budget.

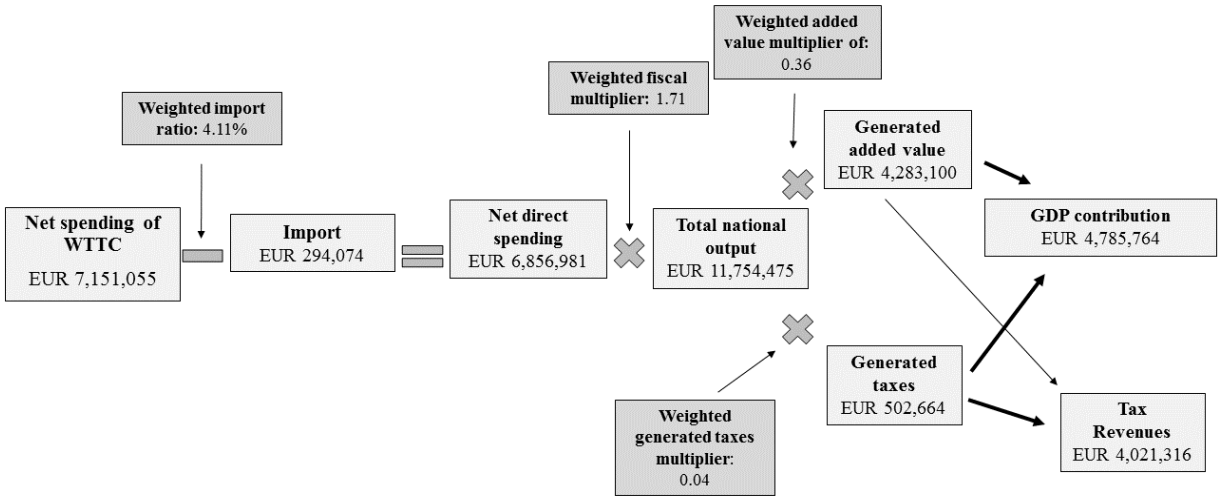

Figure 5. Economic impact of Liebherr 2019 WTTC

Gross financial subsidy of the Hungarian government was 3.95 million EUR. The hypothesis of the study was verified, the Liebherr 2019 ITTF World Table Tennis Championships contributed more to the Gross Domestic Product of Hungary (4.78 million EUR) than the subsidy it has got from the government. Even the tax revenues the Hungarian Central Budget realized related to event were higher (4.02 million EUR) than the subsidies.

DISCUSSION

Laczkó and Stocker (2018) calculated economic impact of international racket sports events organised in Hungary with which the WTTC can be compared with as it can be seen in table 3.

Table 3.
Economic impact per participant of international sports events in racket sports in Hungary

Impact per participant (person)	Net spending	Total National Output	GDP contribution	Tax revenues
LIEBHERR 2019 ITTF World Championship	617 EUR	1,015 EUR	413 EUR	347 EUR
Table Tennis World Tour 2017	233 EUR	374 EUR	158 EUR	102 EUR
Table Tennis U13 Hungarian Open 2017	307 EUR	490 EUR	203 EUR	133 EUR
Badminton U18 Hungarian Open 2017	265 EUR	437 EUR	184 EUR	132 EUR

Source: Authors' compilation based on Laczkó & Stocker (2018) p. 72

The different sizes of the events are clearly shown in the table, but average spending and contribution also vary. Net spending per participant was 617 EUR in WTTC whereas 233 EUR in World Tour, 307 EUR in U13 Hungarian Open and 307 EUR in Badminton U18 Hungarian Open. This shows that those who came to the Table Tennis World Championships were willing to spend significantly more than those who came to smaller international events. This is supporting expectations however as if someone comes to a major event then he/she is willing to pay more. We can also understand that the spending in U13 Hungarian Open was higher than in the other two remaining events as with young children parents also travel, who are eager to spend more. Tax revenues per participant is very interesting as these averages shows that at least how much money is a participant worth in government subsidy. As in most cases significant immaterial value is created besides the economic value (Stocker, 2013), therefore if an event's tax contribution can break even on the government subsidy all immaterial value would be a net benefit. WTTC contributed 347 EUR per participant tax revenues to the Hungarian Central Budget, whereas World Tour contributed 102 EUR, U13 Hungarian Open 133 EUR and Badminton U18 Hungarian Open 132 EUR per participant.

According to empirical results domestic spectators are elemental in international sports events organised in the European Union as their proportion is from 70% to 99% of all spectators depending on the given sports (Schwark, 2005; Sportcal Global Communications, 2017; Laflin, 2018; Sportcal Global Communications, 2019a; Sportcal Global Communications, 2019b). However the proportion of domestic spectators was only 59% is at WTTC. This difference is due to the favourable geographic and economic situation of Hungary in this aspect, namely that Budapest is very easy to reach from other European countries with around 1-2 hour flight. The purchasing power of most European spectators are very strong if they spend in Hungary. These make a world championship in Budapest easy to reach and affordable.

According to Sportcal Global Communications (2018) the daily spectator expenditure was 116.8 EUR in the World Games 2017 which was organised in Wroclaw. The average total expenditure was 138 EUR per spectator at the IFF Men's World Floorball Championships 2018 in Prague which was 37.5 EUR per day for domestic (Czech) spectators and 96.25 EUR per foreign visitors. In contrast daily expenditure of foreign visitors was 128.2 EUR and 624 EUR for the entire stay while 47.9 EUR per day and 122.6 EUR for the entire competition at WTTC (Sportcal Global Communications, 2017; Sportcal Global Communications, 2019b).

The organisation of the competition was rated on average 4.27 by all respondents (SD = 0.92), which can be considered a favourable rating mainly in view of the fact that 86.6% of the respondents rated the event as 4 or 5. However if we compare the participants (mean = 4.24; SD = 0.85), the foreign spectators (mean = 4.26; SD = 0.80) and the Hungarian spectators (mean = 4.30; SD = 1.11), it can be stated that Hungarian spectators rated the organisation significantly better than foreign spectators and participants (χ^2 = 10.648; p = 0.005).

The proportion of foreigners was high (41%) among the spectators, which may be explained by Hungary's favourable transport and geographical situation, relative low prices, the popularity of Budapest among Chinese tourists and the fact that an event of similar importance has not been held in the CEE region for more than a decade.

The groups participating in the WTTC spent a total of more than 30,000 guest nights (30,060 nights) in Budapest, of which 71.8% were spent in a hotel with at least a three-stars rating.

It is important to emphasize from tourism's perspective that foreigners (spectators and participants together) coming to Budapest due to the WTTC considered the hospitality of the Hungarian people very favourable (an average of 4.61 on a scale of 1-5; SD = 0.64), which was significantly associated with a favourable trend in the willingness to return. 57.1% of foreigners plan to return to Hungary within 5 years, but among those who rated hospitality as 5, this proportion was already 62.2%. More than half (55.8%) of the WTTC's foreign spectators and participants took time to visit one or more sights of the capital.

A higher willingness to spend compared to the general tourists and the general sports tourists was clearly identifiable for both domestic and foreign spectators. This can be explained by the location of the competition, which is the settlement with the highest price level and the widest range of tourist offers in Hungary. The peculiarity of the WTTC is that the most important table tennis manufacturers and distributors in the world came to the event venue with special offers which encourages spectator groups to buy table tennis related goods.

The 2019 WTTC set a record in terms of media. TV channels broadcasted in 145 countries in 1176 hours, reaching 665 million viewers (of which 558 million people were in China, where the number of unique viewers reached almost 150 million). Internet streaming broadcasts were followed over 8 days in 148 countries, for which 4.8 million searches were registered. In the case of social media interfaces viewers watched 34.7 million minutes on the event's YouTube channel, while 27.56 million impressions were registered on Facebook (Péli, 2019).

CONCLUSIONS

Foreign passive sports tourists coming to the WTTC spent more time at the event and other tourist attractions than foreign general tourists or sports tourists. Average spending of both foreign and domestic passive sports tourists was higher than foreign or domestic general or sports tourists respectively. The full experience package was important for the spectators in addition to the attractiveness of the event, but almost half of the participants also had additional experiences in Hungary beyond the competition.

It can be said that there is a justification of organising world sports events in Hungary for Olympic sports based on the responses of the spectators and participants and their consumer behaviour. Both the Hungarian organisation and hospitality are so high level that the respondents would like to return to the country in the near future, when they will spend again to fuel the Hungarian economy.

The Hungarian government provided almost 4 million euros support to the organisers of the WTTC. Examining the macroeconomic effects of the competition, it can be stated that every EUR of government support increased the country's GDP by 1.21 EUR and generated a tax of 1.01 EUR in 2019. Expenditures of spectators and participants contributed 24% of the generated GDP, which were not part of the WTTC budget.

Regarding the macroeconomic effects of the WTTC, it can be said that it contributed more than 4.7 million EUR to Hungary's GDP which is more than the subsidy given by the government because of the event. WTTC generated 2.9 million EUR in VAT revenue for the budget and further 1.1 million EUR additional tax revenue for the government's budget. The WTTC's economic impact generated extremely low amount of imports and most of the WTTC related expenditures were spent within the country.

There were also positive sports policy effects in addition to the economic and tourism related effects and Budapest became a focal point in the international media during the competition.

There are also some limitations on the use of input-output modelling in the international literature when estimating the complex economic impacts of sports

competitions (Vörös & Koppány, 2019). These include supply-side income leakage, one-sided interpretation of demand growth, crowding-out and substitution effects. When quantifying the macroeconomic effects generated by the WTTC some of the mentioned methodological shortcomings do not appear (due to the size of the event) and we tried to handle the constraint related to domestic viewers (substitution effect).

We consider it important to monitor the macroeconomic impact of other world table tennis events in the future, taking into account the local specificities of the host countries, which can contribute to a well-founded tendering process for the organisation of these events. Particular emphasis may also be placed on the ITTF's current efforts to transform adult and youth competition series into a new, even more business-based type.

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Original Investigation

Job satisfaction and job commitment of Greek tennis, table-tennis and badminton coaches

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Abstract

The aim of the study was to investigate job satisfaction and job commitment of coaches of the three major racket sports in Greece: tennis, table-tennis and badminton. One hundred and ten (N = 110) tennis (N_T = 61), table-tennis (N_{TT} = 31) and badminton (N_B = 18) coaches responded to the Coach Satisfaction Questionnaire (CSQ), an eleven-factor instrument which assesses coaches' job satisfaction and to the Occupational-Organizational Commitment Scale, a six factor questionnaire which evaluates the different forms of occupational and organizational commitment. Forty six of the coaches were full-time (N_{FT} = 46) whereas of the rest, sixty four were part-time (N_{PT} = 64). The results of a series of t-tests, ANOVAs and correlation analyses revealed various significant differences and relationships. Some of the most important are that: a) tennis coaches and full-time coaches were more satisfied in most of the job satisfaction dimensions, b) significant correlations were noticed between "job satisfaction" and "organizational commitment" variables, c) "autonomy", was a predictor of "organizational affective commitment", d) "satisfaction with coaching job" was the unique predictor of occupational affective and "occupational normative commitment" and e) "team performance" was the only predictor of "occupational continuance commitment". Most of the results are in accordance with the existing job satisfaction literature however, further research is needed on human relation practices of National Federations and/or sport clubs associated with them, in order to have a better understanding of how certain practices and policies lead to higher levels of job satisfaction, organizational and occupational commitment among racket sport coaches.

Keywords: *Job satisfaction, job commitment, racket sports.*

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INTRODUCTION

Job satisfaction is one of the most researched concepts in the field of organizational psychology and it is connected to many and diverse psychological and organizational issues such as burnout, turnover, absenteeism, life satisfaction, job design, performance, emotional labour, leadership, organizational commitment and occupational commitment. From early (Gillet & Schuwab, 1975; Herzberg, Mausner, & Snyderman, 1959) to the most recent research (Abuhashesh, Al-Dmour, & Masa'deh, 2019), the connection between job satisfaction to performance and productivity adds value to the concept, offering practitioners a useful tool for understanding and improving organizational environment, targeting organizational success.

Researchers seem to agree on the multidimensionality of job satisfaction (Courtney & Younkyoung, 2017; Robbins & Judge, 2018; Spector, 1997). Pay, colleagues, advancement, working conditions, social recognition, supervision, nature of the job, job autonomy and job security are the most frequently researched dimensions of job satisfaction. Lately, corporate social responsibility has been proved to influence job satisfaction (Robbins & Judge, 2018).

Job satisfaction is usually studied together with other job attitudes such as job engagement, organizational commitment, perceived organizational support and/or together with the resulting behaviors of job satisfaction (absenteeism, "goldbricking" – someone being at the working place but doing less work than he/she is able to, performance, withdrawal). Job satisfaction has also been found to lead to certain positive results such as high job performance (Schleicher et al., 2015), customer satisfaction (Hoseong & Beomjoon, 2012), life satisfaction (Drakou, Kambitsis, Charachousou, & Tzetzis, 2006) and organizational citizenship behavior (Podsakoff, Podsakoff, & McKenzie, 2014).

Another highly researched job attitude is organizational commitment (Erdheim, Wang, & Zickar, 2006; Grobler & Govender, 2017). It depicts the total participation of an employee in all organization's activities and it includes the extensions of the efforts that the employee puts in these activities. The fact that total commitment contributes in organizational success makes organizational commitment an area of interest for practitioners too (Chelladurai, 1999). Organizational commitment is generally defined as the degree to which an employee is loyal to his/her organization (Nath Gangai & Agrawal, 2014). Meyer and Allen (1991) conceptualized a three component model of organizational commitment which includes affective, normative and continuance commitment. Affective commitment refers to an employee's "emotional attachment to, identification with, and involvement in an organization" (Meyer & Allen, 1991, p. 67). It represents an employee's positive emotional reaction to the organization (Watson & Clark, 1997). Normative commitment represents an employee's feelings of obligation to remain in his/her organization. Finally, continuance commitment is the attitude an employee adapts from his/her perceptions of employment alternatives. Precisely, employees who believe they have several viable alternatives will have lower continuance commitment than those who believe they have few alternatives (Meyer & Allen, 1997). "Continuance commitment reflects high perceived costs of quitting" (Snape, Wing-Hung Lo, & Redman, 2008, p. 5). These costs can be either work or non-work related (Erdheim et al., 2006).

Occupational commitment is another important job attitude and it becomes more important especially if employees transpose their commitment towards their occupations, whereas careers built in a single organization become rare and more uncertain (Lee, Carswell, & Allen, 2000). According to Lee and his colleagues (2000) it is defined as a psychological link between a person and his/her occupation that is based on an affective response to the occupation. Barnhill and colleagues (2018) argue that occupational commitment is an extension of organizational commitment since it shares the same three component multidimensionality of organizational commitment mentioned above. Existing research findings revealed positive relationships between elements of the two types of commitment. In particular, Yousaf, Sanders, and Abbas, (2015) using a sample university employees noticed that organizational and occupational affective commitment were positively related to each other. Speaking of sport coaches, affective occupational commitment would characterize one's strong desire to remain in the profession of coaching because it is something the individual wants for various reasons (sport enjoyment, personal investment, enjoying mentoring, etc.). Normative occupational commitment represents the feeling that one ought to remain a sport coach because he/she owes to the profession. Finally, continuance occupational commitment is the recognition of costs associated with quitting coaching (late entering to another profession, lack of community recognition and lack of competitiveness that sport originally has).

Job satisfaction and Commitments

A lot of research has stabilized the opinion that job satisfaction and organizational/occupational commitment correlate to each other (Iverson, 1992; Lincoln & Kalleberg, 1990; Mueller, Boyer, Price, & Iverson, 1994; Srivastava, 2013; Wallace, 1995). However, longitudinal investigations which attempted to determine whether one can be the cause of the other, do not provide significant and solid results.

Many researchers came to the conclusion that there is a significant relationship between job satisfaction and organizational commitment (Ahmad, Ahmad & Shah, 2010; Mokoena & Dhurup, 2019; Suma & Lesha, 2013; Vandenbeghere, 2008). Similarly, job satisfaction

and occupational commitment seem to be related by a statistically significant positive correlation (Wang, Tao, Ellenbecker, & Liu, 2011). They are both considered as major predictors of the intention to continue in a profession (Satoh, Watanabe, & Asakura, 2016).

Traditionally, literature assumes that satisfaction causes commitment (Lincoln & Kalleberg, 1990; Mueller, et al., 1994; Wallace, 1995). According to the Causal Model of Currivan (1999), job satisfaction together with individual characteristics shapes a certain level of organizational commitment, which, in turn, has an impact on intent to stay. On the other hand, some studies have found that commitment precedes satisfaction (Bateman & Strasser, 1984; Vandenberg & Lance, 1992) while other studies have concluded a reciprocal relationship between the two concepts (Lance, 1991; Lincoln & Kalleberg, 1990; Mathieu, 1991).

Job satisfaction and commitments in sporting environment – relevant studies

Many studies have investigated job satisfaction of sport coaches (Chelladurai & Ogasawara, 2003; Drakou, 2006; Mokoena & Dhurup, 2019) or sport administrative personnel (Bradford Conant, 2017; Fiúekçioglu & Savaú Duman, 2010; Rintaugu, 2013). In particular, Drakou, Charachousou, Kambitsis, and Tzetzis (2008) investigated sport coaches' satisfaction in Greece among coaches of 11 different sports, using the Coach Satisfaction Scale (CSS) (Drakou, 2006) which explores nine dimensions of job satisfaction; supervision, nature of coaching, sport club's tactics, colleagues, salary, coaching conditions, athletes' performance, social dimension of coaching and professional development. Football coaches had the higher level of satisfaction in all dimensions, whereas coaches of rhythmic gymnastics, athletics, rowing and swimming had the lowest level of satisfaction in most of the dimensions. Comparing team and individual sport coaches it was found that coaches of team sports had significantly higher level of satisfaction in six out of the nine dimensions.

Using the same scale (CSS), Salonikidis, Drakou and Koukouris (2007) explored the role that gender, age and coaching experience play in job satisfaction of tennis coaches. Overall, it was found that coaches were satisfied with job nature, job social dimension and colleagues, moderately satisfied with their supervisors, athletes' performance and salary and less satisfied with their clubs' policies and the training conditions. No differences were found between male and female coaches. However, coaches with many years of coaching experience were significantly less satisfied with their supervisor than coaches with less experience.

More recently, Mokoena and Dhurup (2019) explored the relationships among self-efficacy, organizational commitment, job satisfaction and satisfaction with life, using a sample of amateur sport coaches in South Africa. The results of the study indicated that there were significant positive relationships between organizational commitment and job satisfaction, self-efficacy and organizational commitment, organizational commitment and satisfaction with life and self-efficacy with satisfaction with life.

Accordingly, Chelladurai and Ogasawara (2003) studied both job satisfaction and commitment of American and Japanese Collegiate Coaches. The results showed that there were significant differences between the two nationalities. Japanese were significantly less satisfied than Americans regarding seven dimensions of job satisfaction. Regarding commitment, Americans were found to be more committed to their occupation, whereas Japanese were more committed to their sport organizations.

Turner and Chelladurai (2005) explored organizational and occupational commitment, job satisfaction, withdrawal behaviors and performance in head coaches at NCAA Division I and III institutions. Intercollegiate athletic coaches had the highest scores for affective commitment, both organizational and occupational. They had the lowest scores for continuance commitment, both organizational and occupational again. Regarding differences between organizational commitment and occupational commitment, coaches were found to be higher in commitment to their occupation, only in the affective dimension of commitment.

Moreover, Takamatsu and Yamaguchi (2018) studying the effect of coaching behaviors on job satisfaction and organizational commitment in comprehensive community sport clubs in Japan, found that job satisfaction positively impacted organizational commitment. They went on to conclud that autonomy and the existence of a communication friendly space are necessary pre-requisites to increase coaches' job satisfaction and organizational commitment.

The employment status (full time / part time) is a topic which received much research interest in various jobs such as salesmen (Jackofsky & Peters, 1987; Karatuna & Basol, 2017), college instructors (Liu & Zhang, 2015), employees in the financial services industry (Clinebell & Clinebell, 2007) and hospital employees (Eberhardt & Shani, 1984), providing however conflicting results. In some cases, part time employees were found to be more satisfied in overall job satisfaction than full time employees (Eberhardt & Shani, 1984; Jackofsky & Peters, 1987), while other studies ended up with the opposite result (Barling & Gallagher, 1996; Feldman, 1990). Barling and Gallagher (1996) stated that although overall job satisfaction is often equal between full-time and part-time employees, part time employees may be more satisfied with social aspects of the job, such as colleagues and supervision and moreover, they may be less satisfied with rewards.

Regarding sport environment, Robbinson, Peterson, Tedrick, and Carpenter (2003), in their study of NCAA Division III sport administrators, found that full time administrators were more satisfied. In her study in four-year institutions in California, Snyder (1990) found no differences between full time and part time sport coaches in job satisfaction facets. It is true that the number of people working part time is constantly increasing and changing the working landscape we knew until now (EU Labour Force Survey, 2018). Due to this fact and together with the increase of insecurity at work which is originated by the current economic dynamic, it was expected to find differences in the levels of job satisfaction between full-time and part-time coaches, especially in the dimensions of job security and pay.

The present study attempts to explore the possible differences in job satisfaction dimensions and commitments among coaches of the three major racket sports in Greece (tennis, table-tennis and badminton). Moreover, coaches' employment status (full-time/part-time) was investigated, since it has not been studied thoroughly in the Greek sport environment and not studied at all in the Greek racket sport environment. As a final point, the associations between the dimensions of job satisfaction and commitments will be explored. The interpretation of possible specific relations between these variables could help human resource management in sport clubs to create policies that would lead their employees to higher levels of these concepts. Regarding these, Llobet's and Fito's (2013) perception was adopted which suggests that job satisfaction and commitments cooperate in obtaining high correlations in cross sectional models. Thus, positive correlations are expected to be found among certain dimensions of job satisfaction, organizational commitment and occupational commitment, which could be valuable to all those who determine the human resource policies and practices in Greek racket sport organizations.

METHOD

Participants

A total of 110 individuals (*N =110, 82: male, 28: female)* with a mean age of 33.43 (*SD*: ± 9.01) years and with 8.44 (*SD*: ± 6.16) years of coaching experience, participated in the study. There were 61 participants (55.5%) who were tennis coaches, 31 (28.2%) who were table-tennis coaches and 18 (16.4%) who were badminton coaches. Coaching was the only employment for 46 (41.8%) of them while 64 (58.2%) had another job at the same time.

Data collection

Data were collected through anonymous paper-pencil questionnaires during national level games. All participants were ensured that their answers will be confidential and that they will be used only for the purpose of the present study.

Measures

Job Satisfaction. Thirty nine items of the Coach Satisfaction Questionnaire, (CSQ, Chelladurai & Ogasawara, 2003) were used to assess coaches' job satisfaction. The original questionnaire is an eleven-factor instrument which is composed of 41 items and was designed to measure job satisfaction of coaches in American and Japanese universities. Five items of the original questionnaire which refer to 'athletes' academic performance' and to 'media and community' support were excluded. The exclusion of these items was decided because it was judged that they did not fit to the Greek national organizational structure of racket sports. In particular, unlike US and Japanese collegiate sports, in Greece there is no connection of tennis, table-tennis and badminton teams with education performance or media's financial support. The remaining 36 items of the questionnaire referred to 'autonomy' (*6 items*), 'coaching job' (*7 items*), 'team performance' (*5 items*), 'supervision' (*5 items*), 'facilities' (*3 items*), 'pay' (*2 items*), 'amount of work' (*3 items*), 'colleagues' (*3 items*) and 'job security' (*2 items*). The Greek version of the instrument has been successfully used in a previous study (Georgiadi, 2008), giving evidence of adequate validity and reliability. The responders were asked to specify the extent of their satisfaction with the statement of each item using a 9-point Likert scale *(1 = not at all, 9 = very much)*.

Occupational and organizational commitment. The Occupational–Organizational Commitment Scale (Meyer, Allen, & Smith, 1993) was used to evaluate participants' occupational and organizational commitment. It consists of two scales of 18 items each, occupational commitment scale and organizational commitment scale, which both in turn consist respectively of three sub-scales referring to three different forms of commitment: affective (*6 items*), continuance (*6 items*) and normative (*6 items*) commitment. This questionnaire has been also used in Greek language showing acceptable validity and reliability (Georgiadi, 2008). Participants were asked to indicate the extent of their agreement with the statement of each item using a 7-point Likert scale *(1 = strongly disagree, 7 = strongly agree)*.

Mean scale scores were computed for every subscale of the questionnaires. Hence, nine new variables were created (*autonomy, coaching job, team performance, supervision, pay, facilities, amount of work, colleagues and job security*) for the Coach Satisfaction Questionnaire and six (*occupational affective commitment, occupational normative commitment, occupational continuance commitment, organizational affective commitment, organizational normative commitment and organizational continuance commitment*) for the Occupational-Organizational Commitment Scale.

Statistical analysis

Cronbach's alpha coefficient was used to assess the internal consistency of the instruments and *Pearson's r* index to explore the correlations between the variables which were created. For the investigation of possible differences between full time and part time coaches and between tennis, table tennis and badminton coaches, a series of *independent samples' t-tests* and *one-way ANOVAs* were used. The *post-hoc test of Scheffe* with a 95% confidence interval was used for the examination of possible differences between coaches of different racket sports. *Cohen's d* and *partial eta squared* coefficients were used for the evaluation of the strength of the differences that were found.

A series of multiple regression analyses with the 'stepwise' method was used for the further investigation of the association between 'commitment' and 'job satisfaction' variables. In each analysis one of the 'commitment' variables served as the depended variable and all the 'job satisfaction' variables as predictors. With the 'stepwise' method, the statistical package determines and enters in the model the subset of the most useful predictors excluding these which do not contribute to the prediction of the depended variable. To ensure that there was not any multicollinearity between the predictors, the Variance Inflation Factor (*VIF*) was calculated. *VIF* values close to 1 indicate that there are not multicollinearity effects on the model (Field, 2009, p. 224).

RESULTS

Full time coaches scored higher in scales assessing 'supervision', 'team performance', 'facilities', 'pay', 'amount of work' and 'job security'. Several differences were found between coaches of different racket sports and more precisely in 'autonomy', 'coaching job', 'supervision', 'pay', amount of work', 'colleagues', 'job security' and 'occupational affective commitment' (Tables 1a & 1b).

Table 2 presents the internal consistency indices of the scales. All *alpha* values were close or over .70 (Cronbach, 1951) giving evidence of satisfactory internal consistency of the questionnaires and were as expected. Almost all 'job satisfaction' variables were highly correlated. The highest significant correlation (r = .66) was noticed between 'autonomy' and 'coaching job' whereas the lowest (r = .26) between 'coaching job' and 'amount of work'. Various correlations were noticed between the commitment variables. The highest significant correlation was noticed between 'organizational affective commitment' and 'organizational normative commitment' (r = .59) while the lowest between 'occupational continuance commitment' and 'organizational affective commitment' (r = .20). The highest significant correlation between the 'job satisfaction' and 'commitment' variables was noticed between 'supervision' and 'organizational affective commitment' (r = .40) whereas the lowest between 'job security' and 'organizational continuance commitment' (r = .20).

The most significant predictors of the three 'occupational commitment' variables were 'job satisfaction' and 'team performance'. 'Job satisfaction' was the only independent variable that was entered into the prediction model of 'occupational affective and normative commitment' whereas 'team performance' was the only that was entered into the prediction model of 'occupational continuance commitment'. With regard to 'organizational commitment' variables, 'supervision' and 'autonomy' were the predictors of 'organizational affective commitment' and 'colleagues' and 'coaching job' were the predictors of 'organizational normative commitment'. Not one of the 'job satisfaction' variables was entered in the prediction model of 'organizational continuance commitment' (Table 3).

Table 1a.
Mean differences in all variables between full time and part time coaches

	Full-time		Part-time				
	M	*SD*	*M*	*SD*	*t*	*Sig.*	*d*
Job Satisfaction							
Autonomy	7.81	.90	7.78	.92	.21	.833	.04
Coaching job	7.67	.88	7.33	1.05	1.79	.076	.35
Team performance	7.44	.81	7.01	1.09	2.19	.031	.44
Supervision	6.86	1.49	5.92	1.62	3.03	.003	.60
Facilities	6.23	2.38	5.18	2.36	2.24	.027	.44
Pay	6.40	1.98	5.14	2.26	3.02	.003	.59
Amount of work	6.08	1.61	5.19	1.42	3.04	.003	.59
Colleagues	7.68	1.57	7.09	1.56	1.87	.064	.38
Job security	6.34	2.01	5.19	1.90	3.05	.003	.59
Occupational							
Affective commitment	5.13	.67	5.08	.62	.39	.695	.08
Continuance commitment	4.65	1.20	4.32	1.19	1.35	.181	.28
Normative commitment	4.63	1.04	4.54	.96	.45	.650	.09
Organizational							
Affective commitment	4.59	.99	4.45	1.00	.67	.499	.13
Continuance commitment	4.38	1.02	4.10	1.15	1.28	.200	.26
Normative commitment	4.93	1.01	4.36	1.02	2.82	.006	.56

Table 1b.
Mean differences in all variables between coaches of different racket sport

	Tennis		Table-tennis		Badminton				
	M	*SD*	*M*	*SD*	*M*	*SD*	*F*	*Sig.*	η_p^2
Job Satisfaction									
Autonomy	7.75	.95	8.12	.87	7.32	.55	4.504_{c}	.013	.082
Coaching job	7.66	.95	7.40	1.12	6.97	.61	3.514_{b}	.033	.079
Team performance	7.19	1.03	7.31	.94	6.92	1.04	.794	.455	.015
Supervision	6.68	1.54	6.09	1.83	5.54	1.23	3.852_{b}	.024	.070
Facilities	5.83	2.35	5.67	2.58	4.90	2.29	.982	.378	.018
Pay	6.61	1.68	4.46	2.40	4.61	2.13	$15.061_{a,b}$	.000	.221
Amount of work	6.03	1.31	4.94	1.84	5.12	1.34	6.418_{a}	.002	.108
Colleagues	7.87	1.17	7.06	1.78	5.84	1.51	$12.632_{a,b,c}$	.000	.201
Job security	6.22	1.78	5.19	2.41	4.69	1.52	5.620	.005	.095
Occupational									
Affective commitment	5.25	.65	4.94	.65	4.88	.47	3.587	.051	.066
Continuance commitment	4.55	1.10	4.05	1.35	4.95	1.03	3.002	.054	.058
Normative commitment	4.65	.98	4.54	1.10	4.39	.82	.435	.648	.008
Organizational									
Affective commitment	4.51	1.10	4.71	.85	4.20	.76	1.475	.234	.027
Continuance commitment	4.11	1.18	4.51	.85	4.03	1.22	1.559	.215	.029
Normative commitment	4.65	1.14	4.79	.91	4.02	.68	2.816	.065	.052

Note: a = statistical differences between tennis and table-tennis coaches ($p < .05$), b = statistical differences between tennis and badminton coaches ($p < .05$), c = statistical differences between table-tennis and badminton coaches ($p < .05$)

Table 2.
Correlations between all the depended variables and Conbach's α of the scales in the diagonal

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Autonomy	.68														
Coaching job	.66**	.77													
Team performance	.54**	.45**	.70												
Supervision	.38**	.52**	.48**	.85											
Facilities	.31**	.32**	.62**	.47**	.91										
Pay	.15	.33**	.31**	.47**	.51**	.77									
Amount of work	.16	.26**	.31**	.44**	.32**	.44**	.68								
Colleagues	.27**	.35**	.41**	.53**	.30**	.46**	.38**	.86							
Job security	.15	.41**	.33**	.42**	.43**	.61**	.49**	.42**	.76						
Occ. affective commitment	.25*	.33**	.12	.12	.03	.17	.09	.11	.17	.67					
Occ. continuance commitment	.19	.22*	.40**	.19	.29**	.18	.15	.14	.19	.15	.72				
Occ. normative commitment	.25*	.37**	.26**	.24*	.24*	.23*	.07	-.01	.21*	.42**	.29**	.70			
Org. affective commitment	.39**	.38**	.26**	.44**	.19	.18	.05	.32*	.11	.21*	.20*	.48**	.78		
Org. continuance commitment	-.01	.08	.06	.13	.13	.09	-.02	.13	.20*	-.16	.12	-.02	.29**	.73	
Org. normative commitment	.24*	.37**	.16	.34**	.11	.20*	.06	.33**	.19	.06	.11	.37**	.59**	.43**	.72

Note: * = $p < .05$, ** = $p < .001$

Table 3.
Stepwise regression analyses of commitment variables

Step	Depended variable	Independed variables	R^2	*F*	R^2 *Ch*	*F Ch*	*β*	*Sig*	*VIF*
	Occupational affective commitment								
1		Coaching job	.081	7.24			.285	.009	1.000
	Occupational continuance commitment								
1		Team performance	.170	17.05			.413	.000	1.000
	Occupational normative commitment								
1		Coaching job	.117	11.27			.342	.001	1.000
	Organizational affective commitment								
1		Supervision	.216	23.35			.464	.000	1.000
2		Supervision	.266	15.25	.051	5.82	.374	.000	1.159
		Autonomy					.243		1.159
	Organizational continuance commitment								
		No variables were entered into the equation							
	Organizational normative commitment								
1		Colleagues	.145	14.59			.381	.000	1.000
2		Colleagues	.209	11.22	.064	6.86	.296	.000	1.113
		Coaching job					.267		1.113

DISCUSSION

Sport coaching is a very demanding profession since it requires technical and tactical knowledge of sport, deep understanding of human movement, managing highly stressed situations, and inspiring people to get the best out of them. People who chose this occupation need to be multi skilled to cope with all these various demands. Sport clubs, on the other hand, seek coaches with the skills above, coaches who strongly believe in the values of coaching and desire to build a career on it (high occupational commitment) and, at the same time, coaches who strongly desire to participate in all club's activities, putting as much effort as they can (high organizational commitment). It is a real asset for sport clubs to have that kind of coaches. As Chelladurai (1999) mentions, total commitment contributes in organizational success and practitioners ought to understand and use this information since success is the key point for every sport organization. Hence, ideally, sport administration uses managerial tools in order to create a motivating environment that could enforce job satisfaction and commitment, such as training, reward system and satisfying working conditions.

To begin with, the present study explored differences in coaches' job satisfaction and in occupational and organizational commitment due to different sport (tennis, table-tennis, badminton) and due to different occupational status (full-time, part-time).

Regarding different sports, various differences were revealed in job satisfaction among coaches from different sports, which could be concluded in that tennis coaches scored higher level of satisfaction with five out of the nine dimensions (autonomy, supervision, pay, colleagues, and job security). Badminton coaches seem to be less satisfied than tennis coaches and in some occasions than tennis table coaches too. A possible explanation might be that tennis is more popular in Greece than the other two racket sports. It involves sponsorships, media interest, and lately world distinguished athletes. Additionally, tennis coaching is an extra service offered in many Greek hotels, villas and resorts. The larger number of alternatives that a tennis coach has in order to find a job, compared to the alternatives of tennis table and badminton coaches, may increase the probability to find a job that will satisfy him/her more. As to the working *status*, according to Llobet and Fito (2013) many conditions have changed globally in working environments (number of occupations at the same time per person, part time occupation, working from home, using new technology) and these may have an effect on job satisfaction. What used to satisfy an employee of the 20th century may differ from what satisfies an employee of 2020. Things change and this happens faster than ever. That is why studying job satisfaction and commitment remains always among the interests of the scientific community. In Greece, it is very common for a coach to have more than one occupation and the results of this study come to confirm this. More than two out of every five coaches have only one occupation. That is, a large percentage of sport coaches have more than one job at the same time. This is in accordance with Eurostat data which show that there is a continuous increase in the number of people working part time (EU Labour Force

Survey, 2018); in 2005, the percentage of part time employees in EU were 15.6 % of total employment, whereas in 2018, this percentage has been increased to 17.8 %. According to this study's results, and as it was expected, full time coaches are significantly more satisfied than part time coaches, with five out of the nine job satisfaction dimensions. More precisely, they are more satisfied with team performance, supervision, facilities, pay and amount of work. Robinson and his colleagues (2003) came to the same conclusion in their study in sport environment, revealing that sport full time administrators were more satisfied with their job than their part time colleagues. However, as it was mentioned in the introduction, results are conflicting (Eberhardt & Shani, 1984; Jackofsky & Peters, 1987; Snyder, 1990).

With respect to the correlations among job satisfaction dimensions, this study, as it was expected, came to prove the strong correlation between "autonomy" and "coaching itself". Autonomy is in the nature of coaching, it is a prerequisite for a coach to train, lead, inspire. This result is in line with Takamatsu's and Yamaguchi's (2018) results in a similar study, where they argue that autonomy is a necessary precondition for increasing coaches' job satisfaction and organizational commitment. Additionally, the results of this study showed the lowest correlation among job satisfaction dimensions between 'coaching job' and 'amount of work'. This comes as no surprise, if one recalls what training is all about; countless repetitions until perfect technique is achieved, late hours training, weekend competition obligations.

Regarding occupational commitment, the results, as shown by the means (Table 1) demonstrated that coaches had the highest score in occupational affective commitment followed by occupational normative commitment. Regarding organizational affective commitment, coaches had the highest scores in normative commitment followed by affective. Continuance commitment, both organizational and occupational, had the lowest scores, which is in accordance with Turner's (2001) study about head coaches at NCAA.

Concerning correlations between organizational and occupational commitments, the results, as shown in table 2, depicted various correlations among the six dimensions, with the highest significant one to be noticed between 'organizational affective commitment' and 'organizational normative commitment'. In other words, coaches with high emotional attachment and identification to their club are more likely to feel obliged to remain to that specific club. Furthermore, from highest to lowest, the correlations below also emerged; organizational affective commitment was significantly correlated: a) to occupational affective commitment, a result that is in accordance with Yousaf' s and colleagues' result in a similar study (2015), b) to occupational normative commitment, and c) to occupational continuance commitment. As Watson and Clark (1997) state, organizational affective commitment represents an employee's positive emotional reaction to the organization. This means that coaches emotionally attached to their club, have positive reactions towards the club and regarding the results of this study they also feel obliged to continue their careers in the profession of coaching. Additionally, regarding the results of this study, they love coaching and have invested time and effort to it, so they do not intent to leave the profession. In parallel, it is in the advance of club administration to seek ways to capture and cultivate organizational attachment of its coaches. If one takes for granted that clubs also invest on their coaching personnel, it should be of their high priority to keep them in their force.

On the topic of "job satisfaction – organizational commitment" relationship, the results of this study are consistent with previous ones (Ahmad, Ahmad & Shah, 2010; Mokoena & Dhurup, 2019; Suma & Lesha, 2013) suggesting that there is a significant relationship between the two concepts. More precisely, "supervision" and organizational affective commitment correlate to each other with the highest score and consequently it was the most important predictor of this dimension. This could be interpreted in that if a coach is satisfied with the way supervision upon his/her job is performed, then s/he is more likely to show affiliative behaviors towards his/her club. Supervision is performed by people (head coach, owner of the club, technical advisor of the sport federation in the case a national coach, etc.). It is therefore included in the social aspects of coaching together with colleagues (Spector, 1997). It seems that social or human relations are the ones that could create affiliation and emotional attachment to the employee towards the organization. In the same manner, Takamatsu and Yamaguchi (2018) mentioned that a working environment where communication with many people is welcomed and encouraged, plays important role in increasing coaches' job satisfaction and organizational commitment. Supervision also was found to correlate to organizational normative and occupational normative commitments, in a way that proper supervision can "create" an informal, psychological contract that "obliges" a coach to remain in the club and in the profession respectively. In line with other studies (Suma & Lesha, 2013) supervision is an important facet of job satisfaction regarding its correlation to commitments.

Regarding the dimension of autonomy, it was found that besides being a predictor of the organizational affective commitment, it also correlates to organizational normative commitment to occupational affective and occupational normative commitment. This is very important information for sport administrators who aim to keep their personnel. It could be used in job design and in policy planning. Giving space to coaches seems to be a component of

the informal, psychological contract mentioned in the previous paragraph that will keep them in the sport club.

As it was expected, satisfaction with coaching job was correlated to all occupational commitment dimensions. Moreover it was the unique predictor of occupational affective and occupational normative commitment and it was also a predictor of organizational normative commitment. It is straightforward that coaches who are satisfied with the nature of coaching, have feelings of affiliation for it, have invested a lot and do not intend to quit. Moreover, regarding organizational commitment, it was found that they were identified to their club and they felt obliged to keep working there, result which is in accordance with Suma's & Lesha's (2013) study upon employees of public sector. The authors above found that satisfaction with work-itself had significant positive influence on organizational commitment of municipality employees.

According to the findings, team performance was correlated to organizational affective commitment, occupational normative commitment and occupational continuance commitment. Additionally from the regression analysis results it was found to be the only predictor of occupational continuance commitment. In other words, coaches who are satisfied with their team or athletes' performance, are emotionally connected to their club, they believe it would cost them to work at another club, since they have invested a lot and are satisfied with the results of their investment. Additionally, they feel obliged to continue in coaching career.

Facilities, were correlated with all the job satisfaction variables and with two of the three occupational commitment dimensions; continuance and normative. In other words, coaches who are satisfied with sport facilities (gym halls, equipment, training conditions) are committed to their job in a way that they feel they have to stay in their coaching career, they owe it to the sport, and changing career would cost them a lot in terms of money, time and effort.

Moreover, this study revealed that pay satisfaction was correlated to normative commitment, both organizational and occupational. This is in line with Vandenbeghere' result in a similar study (2008), and partially in accordance with Turner's study (2001) which showed that pay satisfaction correlates to all the three dimensions of organizational commitment. Nevertheless, it is opposite to the result in Suma's and Lesha's (2013) study, where no correlation between pay satisfaction and commitment was found. However, and regarding this study, money seems to create feelings of obligation; it is in its exchange nature. Coaches of this study were moderately satisfied with their salary, but it seems that even this level of satisfaction keeps them in job and their club, because of feelings of obligation.

Interestingly, there was no correlation between "amount of work" and organizational and occupational dimensions, when explored one by one. As mentioned at the beginning of the discussion, coaching includes a large amount of work, not only considering training hours, but also hours spent in meetings with administrators, parents, athletes, studying and planning at home. Regarding the results, it seems that sport coaches' commitment to both club and occupation is not influenced by hard working. This result comes to reinforce the result of Robinson's and his colleagues' (2003) study for athletic directors, which proved that the amount of time spent on job duties, is not a predictor of job satisfaction.

CONCLUSIONS

Many researchers agree that the relationship with colleagues is one of the major sources of job satisfaction (Drakou, 2006; Rintaugu, 2013; Takamatsu & Yamaguchi, 2018). Regarding this study satisfaction with the relationship with colleagues was among the three highly scored dimensions together with satisfaction with autonomy and coaching itself. The dimension "colleagues" was also found to correlate to organizational affective and organizational normative commitment and according to the regression analysis results it was the most significant predictor of organizational normative commitment. In other words, maybe it is not always important for a club to have the best coaches, but instead it is rather more important to have coaches who enjoy working together. This climate of cooperation can create stronger ties between coaches and sport organization, and that may lead to long-term, successful partnership (Bakotić, 2016; Nilipour Tabatabei, Takapoo, & Leilaeyoun, 2015; Wright, Gardner, Moynihan, & Allen, 2005).

Finally, satisfaction with job security was found to correlate to organizational continuance commitment. This is the only case in the study, where a job satisfaction dimension correlates to continuance commitment. It is straightforward that coaches estimate the costs associated with leaving their club, and their final decision to remain or leave is taken considering what they lose. Job security seems to be a critical factor in this decision.

Limitations

The causal order of job satisfaction and commitments was not of the interest of this paper and this may be considered a limitation of this research. Given the fact that past results did not show any consistency (Llobet & Fito, 2013) this certainly needs to be further explored.

Suggestions

Further research needs to be conducted on the human relation practices of the National Federations

and/or sport clubs associated with them, in order to have a better understanding of how certain practices and policies lead to higher levels of job satisfaction, organizational and occupational commitment among racket sport coaches. Moreover, while research on employment status and job satisfaction has led to contradictory results so far, future research should focus not only on the employment status (full time / part time) but also on the amount of hours spending on coaching in relation with employment status.

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