

Research article

## Incidence Rate of Musculoskeletal Injuries among Professional Tennis Players during 2019 International Tournaments in Indonesia

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### Abstract

Several studies have indicated that musculoskeletal injuries are common during a professional tennis competition. However, data from a tropical country like Indonesia is lacking. This study aimed to obtain the incidence rate and injury characteristics and identify risk factors of musculoskeletal injuries among professional tennis players competing in Indonesia under the International Tennis Federation (ITF). The study was a prospective cohort during professional tennis tournaments in Jakarta, Indonesia in 2019, consisting of the ITF Women's Circuit Indonesia (two weeks) and ITF Men's Future Indonesia (three weeks). All athletes were enrolled in this study. Injuries were assessed based on the ITF Consensus Statement. Incidence rate was the number of injuries per 1000 player hours (i.e., the total duration from before the match starts to completion of the match after the final point). The magnitude of risk was expressed as a relative risk (RR) and its 95% confidence interval (CI). Independent risk factors were identified using multivariate analyses. A total of 161 tennis players were enrolled; 71 (44.1%) were men. Their mean age was 22 years old. The incidence rate of musculoskeletal injuries was 30.8 injuries per 1000 player hours (95% CI: 28.2–33.5). The most common onset was acute injuries (61.1%), while the most common location and type of injury was the trunk (38.9%) and muscle strain (61.1%). Risk factors associated with musculoskeletal injury were higher body height, skill level, history of previous injury, and wet bulb globe temperature (WBGT) zone. There was no injury during the doubles matches. Previous injury was an independent risk factor (adjusted RR: 48.1 (95% CI: 11.3–155.0;  $p < 0.001$ ). The incidence of musculoskeletal injuries among professional tennis player is considerably high. Factors associated with injury are body height, skill level, previous injury, and WBGT zone. Future injury prevention programmes should incorporate the management of previous injuries and take into account the effect of environmental temperature.

**Key words:** Tennis, epidemiology, injury, incidence, risk factors, tropical climate.

### Introduction

Tennis is a popular sport with more than 75 million players from 200 countries, including Indonesia (Dakic et al., 2017). Currently there are more than 1000 professional tennis players registered by the Indonesian Lawn Tennis Association and many more people are playing at the recreational level.

Given the wide popularity of tennis, it is important to evaluate tennis-related injuries and to evaluate its associated risk factors. In contrast to many sports, the duration of a tennis match is not determined by a time limit and can last for several hours. During the match there is repeated

pressure on the musculoskeletal system through a variety of strokes and movements. Consequently, tennis players are prone to various injuries (Fu et al., 2018). In addition, tennis is played in an open environment where the players are exposed to environmental condition. Hot temperature and high humidity are typical in a tropical country; athletes competing in this condition may be exposed to hot and sometimes extreme temperature (Armstrong et al., 2007; Smith et al., 2018).

The International Tennis Federation (ITF) has issued a consensus statement on the epidemiology of tennis medical conditions, which was intended to facilitate standardized documentation and analysis of tennis-related injuries (Pluim et al., 2009). Several studies have cited the ITF consensus statement and showed that injuries are common during professional tennis tournaments. The first study was a report from the US Open Tennis Championship 1994–2019 showing an overall injury rate of 48.1 injuries per 1000 match exposures (Sell et al., 2014). The second study obtained data from The Championships, Wimbledon 2003–2012, which reported an overall rate of 20.7 injuries per 1000 sets played (McCurdie et al., 2017). Then came a study from The Australian Open Grand Slam between 2011 and 2016 that found a higher rate of injuries among female than male players (201.7 injuries vs. 148.6 injuries per 10.000 game exposures) (Gescheit et al., 2015). Another report from The Australian Open Grand Slam from 2014 to 2016 showed that the incidence rate of injury was increased by 55.9% in women matches and 47% in men matches as the temperature increases (Smith et al., 2017a; 2017b).

Most epidemiological studies were performed retrospectively and included only injuries reported to tournament physicians (Fu et al., 2018). Mild injury that could be managed during a match might not be reported; thus, the true incidence rate of injuries might be underestimated. Prospective studies are important to establish a causal relationship for an injury and to develop an evidence-based program for injury prevention and management of risk factors (Bahr and Holme, 2003). Although international tennis tournaments were regularly held in Indonesia, there was no study on tennis-related injury and its associated risk factors in Indonesia, either retrospectively or prospectively. This study was first aimed to know the incidence rate of tennis-related injuries and to characterize them based on the ITF consensus. Secondly, we would like to study the role of environmental temperature and other risk factors of tennis-related injuries among professional tennis players competing in Indonesia.

## Methods

### Study design and subjects

This was a prospective cohort study on tennis players competing in professional tennis tournaments in Indonesia between January and December 2019. There were two series of the ITF Women's Circuit Indonesia and three series of the ITF Men's Future Indonesia. All tournaments were held in Jakarta. All athletes participated in the tournaments were included as the study subjects. All athletes gave their written consent prior to their enrollment in this study. Ethical approval was granted by the Committee of Health Research Ethics, Faculty of Medicine, Universitas Indonesia (certificate number KET-810/UN2.F1/ETIK/PPM.00.02/2019).

### Assessment of injuries

Injuries were recorded and assessed using questionnaires by the research team for each match every day. Data obtained were the round of the match, match type, starting time, completion time, athletes' names, and the injury whenever occurred. Injury was defined as any physical complaint from the athlete whether it needed medical attention or causing discontinuation from the current match (Pluim et al., 2009). Incidence of injuries was reported as the number of injuries per 1000 player hours (Pluim et al., 2009). Player hours was the total of match duration, i.e. before the match starts to completion of the match after the final point (Pluim et al., 2009; International Tennis Federation, 2018).

Based on the mode of onset, injury was categorized as acute (injury due to specific event which identified early or sudden pain or disability), gradual-onset (injury manifested in specific period or when intensity of pain or disability was increased gradually without any identified single event responsible for the condition) or recurrent (injury at the same location and type related with previous injury and happened when athlete was fully participating after the injury) (Pluim et al., 2009).

Location of injury was grouped based on the affected body part, i.e. head and neck, upper extremity, trunk, and lower extremity (Pluim et al., 2009). Type of injury was the athlete's medical condition diagnosed by a

physician (Pluim et al., 2009),<sup>4</sup> and were categorized into 9 types: (1) fracture, (2) dislocation, (3) sprain, (4) meniscal lesions, (5) synovitis, (6) strain, (7) cramp or spasm, (8) tendinopathy, and (9) contusion (Peterson and Renstrom, 2001; Peterson, 2016). In this study, the investigators were also functioned as the ITF medical doctor.

### Risk factors for injuries

Injuries causes are multifactorial, consisting internal and external risk factor, and inciting event (Bahr and Holme, 2003). Internal risk factors analyzed in this study were age, gender, height, weight, previous injury, tennis experience, and skill level, while the external risk factors were the environmental temperature as measured based on the Wet-Bulb Globe Temperature (WBGT) zone and inciting events were the round of match and match load.

Height was measured by using a stature meter (GEA) and body weight was measured using a digital scale (Omron HN-289). Previous injury was any injury in the past 12 months diagnosed by medical doctor or athletic trainer (Hjelm et al., 2012; Dakic et al., 2017). Tennis experience was the number of years playing tennis starting from at the earliest age. Skill level is measured by the athlete's ITF rank. The WBGT zone was the zone recorded during the match when the athlete was injured. The zones were defined based on data from the Indonesian Meteorology, Climatology and Geophysics Council and a local study in Jakarta (Table 1) (Tika, 2010; Wirjohamidjoyo and Swarinoto, 2010). Variables of inciting event were round of match (qualifying or main round) and match load (the number of matches played by the athlete in a day).

### Statistical analysis

The profile of tennis players and injuries were presented descriptively. The incidence rate (IR) of musculoskeletal injuries was expressed as number of injury per 1000 player hours. Subjects were grouped into injured and non-injured. Differences between both groups were tested using t test for normally distributed data or Mann-Whitney U test for skewed data. The association between categorical risk factors and the presence of injury was analyze using the Chi-square test. A p value of less than 0.05 on chi-square test was considered significant. The magnitude of risk was

**Table 1.** Variation of temperature, humidity and WBGT interpretation.

Time	Temperature (C)	Humidity (%)	WBGT (oC)	Zone
06:00	25.20	80.56	28	Zone 3
07:00	26.83	71.21	29	
08:00	28.50	62.13	30	
09:00	30.73	57.48	30	
10:00	32.15	52.80	31	Zone 4
11:00	32.15	50.52	31	
12:00	33.70	45.57	33	Zone 5
13:00	34.03	43.64	33	
14:00	34.45	42.67	34	
15:00	32.33	53.89	32	Zone 4
16:00	30.28	63.05	32	
17:00	28.65	69.25	31	
18:00	26.93	73.45	30	Zone 3
19:00	25.70	81.70	29	
20:00	24.90	89.00	29	

WBGT: wet bulb globe temperature

expressed as a relative risk (RR) and its 95% confidence interval (CI). Multivariate analysis was then performed to identify independent risk factors for musculoskeletal injuries. To prevent for a type 2 error, only variables with a bivariate p-value of 0.20 or less were selected for such multivariate analyses. In this manner, it is assured that all pertinent and potentially predictive variables are studied (Concato et al., 1993). The results were expressed as adjusted relative risks (RRadj) with their corresponding 95% CI. Statistical analyses were performed using SPSS software version 17.0 for Windows PC (SPSS Inc., Chicago, Illinois, USA).

## Results

### Characteristics of the tennis players

A total of 161 tennis players were enrolled in this study; 90 (55.9%) among them were male athletes. The athletes' ranks were widely distributed with the best ranking of singles is 27 and the best ranking for doubles is 13. Most players (63.4%) competed both in singles and doubles matches. Other characteristics were shown in Table 2.

### Incidence rate and characteristics of injuries

Totally, these tournaments spent 1167.7 hours and caused 36 musculoskeletal injuries, bringing an incidence of 30.8 injuries per 1000 player hours (95% CI: 28.2–33.5). The incidence was 35.7 injuries per 1000 player hours (95% CI: 32.1–39.2) in male athletes and 23.6 injuries per 1000 player hours (95%CI: 19.7–27.4) in female athletes.

Acute injuries were the most frequent mode of onset of injuries (61.1%), while the trunk was the most common location of injury (38.9%). The spine erector muscle was

the most common structure affected. Muscle strain is the most common type of injury (Table 3).

### Risk factors of musculoskeletal injury

The body height of players with injury were significantly higher than players without injury. Previous injury was associated with 2.1 times more risk for current injury. There was no injury during the double matches; therefore, only the skill level of singles was analyzed. Higher ITF rank (<742) was associated with 1.3 times more risk to be injured. The WBGT zone 5 is the external risk factor associated with 1.2 times more risk for injury (Table 4). In multivariate analysis, only previous injury was identified as an independent risk factor for the current injury (Table 5).

**Table 2. Characteristics of the tennis players (n = 161).**

Characteristic	n (%)	Mean ± SD or Median(min–max)
Age	–	22.0 ± 4.1
Male	90 (55.9)	–
Female	71 (44.1)	–
Height (m)	–	1.74 ± 0.09
Weight (kg)	–	68.6 ± 10.4
<b>Previous injury</b>		
Present	50 (31.1)	–
Absent	111 (68.9)	–
Tennis experience (years)	–	15 (6–31)
<b>Skill level*</b>		
Singles ranking	–	742 (27–2668)
Doubles ranking	–	595 (13–1886)
<b>Match participation</b>		
Singles	59 (36.6)	–
Singles + doubles	102 (63.4)	–

\*31 athletes did not have an ITF ranking and were not included in the analysis.

**Table 3. Musculoskeletal injuries characteristics (n = 36).**

Characteristic	Characteristic	Men (n = 25)	Women (n = 11)	Total (%)	IR* (95%CI)
Onset	Acute	17	5	22 (61.1)	18.8 (16.6–21.1)
	Gradual	1	2	3 (8.3)	2.6 (1.7–3.5)
	Recurrent	7	4	11 (30.6)	9.4 (7.7–11.1)
Location of injury	Head and neck	0	1	1 (2.8)	0.9 (0.3–1.4)
	Structure affected	–	splenius capitis	–	–
	Trunk	12	2	14 (38.9)	12 (10.1–13.9)
	Structure affected	trapezius	rectus abdominis	–	–
		erector spine (7) external oblique (2) gluteus medius (2)	erector spine	–	–
Upper limbs	Upper limbs	8	1	9 (25.0)	7.7 (6.2–9.2)
	Structure affected	extensor digitorum	rotator cuff	–	–
		wrist (3)	–	–	–
		rotator cuff (2) biceps triceps	–	–	–
Lower limbs	Lower limbs	5	7	12 (33.3)	10.3 (8.5–12)
	Structure affected	quadriceps	quadriceps (4)	–	–
		ankle	hamstring	–	–
		plantar fascia (2)	knee	–	–
		lisfranc joint	peroneus longus	–	–
Type of injury	Strain	16	6	22 (61.1)	18.8 (16.6–21.1)
	Sprain	5	1	6 (16.7)	5.1 (3.9–6.4)
	Tendinopathy/bursitis	4	1	5 (13.9)	4.3 (3.1–5.4)
	Cramp/spasm	0	3	3 (8.3)	2.6 (1.7–3.5)

\*IR: incidence rate per 1000 player hours; CI: confidence interval

**Table 4.** Risk factors associated with the incidence of musculoskeletal injuries.

Risk factor	Injured	Uninjured	RR	95% CI	p	
Internal risk factors	Age	21.9 ± 3.3	22.0 ± 4.3	–	–	0.92
	Height (cm)	178.1 ± 8.0	173.5 ± 9.0	–	–	0.01
	Weight (kg)	71.8 ± 9.5	67.9 ± 10.5	–	–	0.06
	Tennis experience	15 (8–23)	15 (6–31)	–	–	0.79
ITF singles ranking	> 742*	11 (11.5)	85 (88.5)	1.3	1.1 – 1.5	0.004
	< 742	20 (30.8)	45 (69.2)			
Gender	Female	11 (15.5)	60 (84.5)	1.4	0.7 – 2.8	0.280
	Male	20 (22.2)	70 (77.8)			
Previous injury	Absent	4 (3.6)	107 (96.4)	2.1	1.5 – 2.8	<0.001
	Present	27 (54.0)	23 (46.0)			
External risk factor WBGT zone	Zone 4	8 (10.8)	66 (89.2)	1.2	1.0 – 1.4	0.02
	Zone 5	23 (26.4)	64 (73.6)			
Inciting event Round of match	Qualifying	6 (11.5)	46 (88.5)	1.2	1.0 – 1.3	0.09
	Main round	25 (22.9)	84 (77.1)			
Match load	Singles	7 (11.9)	52 (88.1)	1.2	1.0 – 1.3	0.09
	Singles + doubles	24 (23.5)	78 (76.5)			

RR: relative risk; CI: confidence interval; \* includes 31 athletes with no ITF rank.

**Table 5.** Multivariate test for variables associated with the incidence of injuries.

Variable	RR <sub>adj</sub> (95%CI)	p
Higher body height	1.1 (1.0 – 1.2)	0.09
Higher body weight	1.0 (0.9 – 1.1)	0.67
ITF singles ranking <732	2.0 (0.6 – 7.1)	0.27
Positive previous injury	41.8 (11.3 – 155.0)	<0.001
Match load: singles + doubles	1.9 (0.5 – 7.4)	0.33
WBGT zone 5	2.4 (0.7 – 7.6)	0.15
Round of match: main round	1.3 (0.3 – 5.4)	0.71

RR<sub>adj</sub>: adjusted relative risk. CI: confidence interval; WBGT: wet bulb global temperature

## Discussion

We found that the incidence rate (IR) of musculoskeletal injuries was relatively high at 30.8 per 1000 player hours. Previous injury was the only independent risk factor for the current injury. Early report on tennis-related injury during Danish Championship found an IR of 2.3 per 1000 player hours (Winge et al., 1989). Another study during Davis Cup 2006-2013 reported an IR of 6.05 per 1000 player hours (Maquirriain and Baglione, 2016; Fu et al., 2018). Although the level of competition in Davis Cup was higher than ITF tournaments in this current study, lower IR could be due to the difference of competition format. In Davis Cup, the match was held in two days and players could only have two matches at maximum in each series. Besides, each series was separated within two to six months (International Tennis Federation, 2019).

Our study design might also contribute to the higher incidence. Prospective study is the best design among all observational study designs aiming to prove a cause-effect relationship. By recruiting a prospective cohort, all players knew that their injuries would be recorded and this had made them more attentive to report any complain. Prospective study from the Australian Open – WTA Tour 2015 found an IR of 56.6 (95% CI: 49.5-64.6) per 1000 player hours (Dakic et al., 2017). On the contrary, retrospective studies often relied on the physician's report after a tournament and might overlook injuries occurring and managed during a match.

Most injuries were acute in onset, located in the trunk and typically were muscle strain. Interestingly, lower

back injuries were common, mainly affecting the group of spine erector muscles. Acute injuries in sports are common in a recent review (Fu et al., 2018). Muscle strain was also reported in previous studies as the most common type of injury (Sell et al., 2014; Gescheit et al., 2015; Dakic et al., 2017). Lower limb was the most frequent site of tennis-related injury found in many studies, such as the US Open Tennis Championships (Sell et al., 2014), Wimbledon Championship (McCurdie et al., 2017), Davis Cup (Maquirriain and Baglione, 2016), and the 2015 Australian Open – WTA Tour (Dakic et al., 2017). However, spine muscle injuries were the leading area of musculoskeletal injury documented online by the Association of Tennis Professionals (ATP). These unpublished data showed that the number of spine muscle injury was increased from 290 in 2012 to 580 in 2016 (Fu et al., 2018). High prevalence of lower back injury was also showed among the US junior tennis players (3.4 case per 1000 players) (Hutchinson et al., 1995; Kovacs et al., 2014). The cause is probably related to the large lumbar spinal loads during serve. In advanced tennis player, shear effect due to body axis rotation and repetitive hyperextension posture with profound front-back and bilateral co-activations in lower trunk muscles were known to be the mechanism causing lower back injury (Chow et al., 2009).

We found four risk factors that significantly associated with the incidence of musculoskeletal injury, i.e. higher body height, higher skill level, a history of previous injury within the last 12 months, and WBGT zone 5. Only previous injury was identified as independent risk factor for the current injury.

Body height could be a risk factor of injury because it is associated with higher weight and pressure received by the muscles, joints and ligaments. However, the exact mechanism is still unclear (Murphy et al., 2003).

Higher single ITF rank athlete was associated with increased risk of injury. Previous study among the WTA players showed similar results in which, higher athlete's single rank significantly associated with the numbers of injury in each season ( $p = 0.002$ ) (Dakic et al., 2017). WTA houses top female tennis players who ranked above the ITF ranking system (Women's Tennis Association, 2019). High-ranked tennis players are likely to get injured since they could play more matches than the low-ranked ones who have been ruled out earlier (Dakic et al., 2017). Additionally, high-ranked athletes might have more exposures of trainings and matches that put them at higher risk of injury (Pluim et al., 2006). A study showed that tennis players who played in successive days showed decreased performance, increased creatinine kinase level, then increased level of pain and fatigue, suggesting that the same thing happened when they continue to the next round (Gescheit et al., 2015).

A history of previous injury was the most important risk factor of developing current injury in this study. A systematic review found that one of the most significant risk factors of injury in any body parts is previous history of injury without considering the location ( $p = 0.002$ ) (Hjelm et al., 2012; Oosterhoff et al., 2019). Athletes who were previously injured had 10 times higher risk to be injured. On the lower extremity, the risk of injury increased 18.6 times higher among athlete who had previous injury than had no previous injury (Hjelm et al., 2012). It could be caused by incomplete recovery of the previous injury or there was an altered biomechanical movement pattern causing excessive load in other structure that responsible for the new injury (Dallinga et al., 2019).

WBGT zone 5 is characterized with high temperature beginning at noon until 3 pm in the afternoon. Higher incidence of injury might be due to higher fatigue level in a hot climate. Core body temperature, heart rate, blood lactate, and fatigue level are progressively increased during a match in hot temperature (Périard et al., 2014). At the cellular level, the injured muscle has sarcomere damage characterized by disruption of Z-line due to interdigital change of thin and thick filament. Besides, fatigue muscles is disrupted due to  $Ca^{2+}$  influx from interstitial fluid from phospholipase activation accompanied by release of fatty acid and further oxidation to produce free radical which lower the capability of muscle contractile element to absorb energy hence susceptible for injury (Dugan and Frontera, 2000).

Our results may implicate to the future management of professional tennis players. Understanding the risk factors of injury is important both for players and medical team and to design prevention program. For example, exercise program for muscle strengthening, especially at the back, may be offered to prevent spine muscle injury. Collaboration between tennis professional organization and sports medicine physicians should be enhanced, especially during injury recovery program, so injury can be treated properly ensuring that the athlete is fully recovered before

entering next tournaments. During a match in a hot climate, particularly WBGT zone 5, medical team may provide sufficient ice towels for the players to reduce body temperature (Schraner et al., 2017).

There are some limitations in our study. First, we did not have medical record data on previous injury and analyze its association with the current injury. Secondly, we did not assess injury severity as well as the loss of time from competition. Furthermore, there is no incidence of injury in doubles subcategory; therefore the current analysis may not be generalized to all tennis players. Lastly, this current study is mainly focusing on injuries during international tournament; the result may be different in the context of training.

## Conclusion

This prospective study has demonstrated that the incidence rate during international tournaments in Indonesia is relatively high (30.8 per 1000 player hours). The most common characteristics of injury are acute onset, located in the trunk and mainly occur as muscle strain. Higher body height, higher skill level, previous injury history, and WBGT zone 5 are significantly associated with the injury; however, the presence of previous injury is the only independent risk factor. An understanding of the characteristics of the injury and the associated risk factors may aid in the development of a prevention programme and risk identification in the future tournaments, particularly those conducted in tropical climates.

## Acknowledgements

The Research was funded by the Universitas Indonesia Research Grant PITTA B 2019. The experiments comply with the current laws of the country in which they were performed. The authors have no conflict of interest to declare. The datasets generated during and/or analyzed during the current study are not publicly available, but are available from the corresponding author who was an organizer of the study.

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### Key points

- Incidence rate are often obtained retrospectively; a prospective study should be more accurate.
- Acute injuries during international tournaments frequently occur, mostly due to muscle strain.
- Exposure to higher temperatures in tropical countries with high humidity has the potential to increase the risk of injuries.
- History of previous injury is the most important risk factor for current injuries that should be identified before a tennis player enters a tournament.

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