

นิพนธ์ต้นฉบับ (Original article)

ชีวกลศาสตร์ทางกีฬา (Sports Biomechanics)

## GROUND REACTION FORCE AND LOADING RATE DURING SEPAKTAKRAW SPIKE LANDINGS

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### ABSTRACT

Sepaktakraw spike landing is a sport-specific landing that may prone to injury due to high impact force. Because of there are limited research in sepaktakraw particularly when landing. To understand ground reaction forces can provide insights of sepaktakraw spike landings. Therefore, the purpose of this study was to investigate ground reaction forces (PVGRF), time to PVGRF (TTPF) and loading rate (LR) among different sepaktakraw spike landings. Ten collegiate male sepaktakraw athletes ( $\bar{x}_{age}$  19.6±2.8 years,  $\bar{x}_{weight}$  61.4±7.2 Kg and  $\bar{x}_{height}$  1.74±0.04 m) performed three sepaktakraw spike landings (roll spike (RS), half roll spike (HS) and sunback spike (SS)) onto a force plate. Five successful trials of each spike landing were averaged. One-way repeated measurement ANOVA revealed significant differences of PVGRF, TTPF and LR among three spike landings ( $p<0.05$ ). Post-hoc analysis found significant differences of all parameters between RS vs. HS and RS vs. SS, but no significant difference between HS and SS. RS landing demonstrated the greatest PVGRF (3.97±0.76BW) and LR (158.8±64.8 BW/s) and the lowest TTPF (30±10 ms). In conclusion, roll spike may be at high risk of injury as compared to half-roll spike and sunback spike landings due to the high loading rate.

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KEY WORDS: Sepaktakraw, Landing, Ground reaction force

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## แรงปฏิกิริยาจากพื้นและอัตราการเกิดแรงในขณะกระโดดลงสู่พื้นจากการกระโดดฟ้าดของเชือกตะกร้อ

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### บทคัดย่อ

การลงสู่พื้นจากการกระโดดฟ้าดของเชือกตะกร้อเป็นการลงสู่พื้นที่เฉพาะของกีฬาเชือกตะกร้อ ซึ่งอาจจะมีแนวโน้มของการบาดเจ็บ เพราะว่ามีแรงกระแทกสูง และเนื่องจากมีการวิจัยที่จำกัดในกีฬาเชือกตะกร้อ โดยเฉพาะเมื่อลงสู่พื้น เพื่อทำความเข้าใจถึงแรงปฏิกิริยาจากพื้น ซึ่งสามารถทำให้เข้าใจถึงการลงสู่พื้นจากการกระโดดฟ้าดของเชือกตะกร้อ ได้มากขึ้น ดังนั้นจุดประสงค์ของการศึกษานี้คือ เพื่อทดสอบความแตกต่างของแรงปฏิกิริยาจากพื้นสูงสุดในแนวตั้ง ระยะเวลาที่ใช้ในการเกิดแรงปฏิกิริยาจากพื้นสูงสุดในแนวตั้ง และอัตราการเกิดแรงในขณะกระโดดลงสู่พื้นจากการกระโดดฟ้าดของเชือกตะกร้อทั้ง 3 ท่า โดยใช้นักกีฬาเชือกตะกร้อชายระดับมหาวิทยาลัย จำนวน 10 คน (อายุเฉลี่ย  $19.6 \pm 2.8$  ปี น้ำหนักเฉลี่ย  $61.4 \pm 7.2$  กก. และความสูงเฉลี่ย  $1.74 \pm 0.04$  ม.) ทำการกระโดดลงสู่พื้นจากการกระโดดฟ้าดของเชือกตะกร้อทั้ง 3 ท่า (การกระโดดฟ้าดแบบเต็มรอบ, การกระโดดฟ้าดแบบครึ่งรอบ และการกระโดดฟ้าดแบบชั้นเบ็ค) ลงบนแผ่นวัดแรงกระแทก โดยทำท่า ๆ ละ 5 ครั้ง และนำมาคำนวณเฉลี่ย เพื่อนำมาใช้ในการวิเคราะห์ One-way repeated measurement ANOVA แสดงให้เห็นว่า แรงปฏิกิริยาจากพื้นสูงสุดในแนวตั้ง ระยะเวลาที่ใช้ในการเกิดแรงปฏิกิริยาจากพื้นสูงสุดในแนวตั้ง และอัตราการเกิดแรงในขณะกระโดดลงสู่พื้นจากการกระโดดฟ้าดของเชือกตะกร้อทั้ง 3 ท่า มีความแตกต่างกันอย่างมีนัยสำคัญทางสถิติ ( $p < 0.05$ ) Post-hoc analysis พบความแตกต่างอย่างมีนัยสำคัญทางสถิติในทุกตัวแปรระหว่างการกระโดดฟ้าดแบบเต็มรอบกับการกระโดดฟ้าดแบบครึ่งรอบ และการกระโดดฟ้าดแบบเต็มรอบกับการกระโดดฟ้าดแบบชั้นเบ็ค แต่การกระโดดฟ้าดแบบครึ่งรอบกับการกระโดดฟ้าดแบบชั้นเบ็ค ไม่มีความแตกต่างกัน การกระโดดฟ้าดแบบเต็มรอบมีแรงปฏิกิริยาจากพื้นสูงสุดในแนวตั้ง ( $3.97 \pm 0.76$  เท่าของน้ำหนักตัว) และอัตราการเกิดแรง ( $158.8 \pm 64.8$  เท่าของน้ำหนักตัวต่อวินาที) มากที่สุด และยังมีระยะเวลาที่ใช้ในการเกิดแรงปฏิกิริยาจากพื้นสูงสุดในแนวตั้ง ( $30 \pm 10$  มิลลิวินาที) น้อยที่สุด สูงผลการศึกษาในครั้งนี้ การกระโดดฟ้าดแบบเต็มรอบอาจจะมีความเสี่ยงของ การบาดเจ็บสูงจากการกระโดดลงสู่พื้น เมื่อเปรียบเทียบกับการกระโดดฟ้าดแบบครึ่งรอบและการกระโดดฟ้าดแบบชั้นเบ็ค เนื่องจากมีอัตราการเกิดแรงสูง

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คำสำคัญ: เชือกตะกร้อ, การลงสู่พื้น, แรงปฏิกิริยาจากพื้น

## INTRODUCTION

Sepaktakraw is a popular sport in the Southeast Asia particularly in Thailand and Malaysia. Currently, there are 28 national associations around the world joining the International Sepaktakraw Federation (ISTAF) (1). According to the ISTAF rule, a sepaktakraw team consists of three players. Each position has a different role; thus, each player must possess specific skill for his position. For example, sepaktakraw spike is essential skill for a scorer. In general, there are 3 common types of sepaktakraw spike which are roll spike (RS), half-roll spike (HS) and sunback spike (SS). Roll spike is similar to a full circular somersault kick in a football while half-roll spike is executed only a half-circular somersault kick. Sunback spike, on the other hand, is commonly performed by kicking over a player's shoulder.

Sepaktakraw spike is an aggressive motion that requires a forceful kick a takraw ball in the air to generate ball speed. A prospective cohort study stated that the incidence of sepaktakraw injuries was greater than soccer (2). Additionally, they reported that landing from spike was one of a major cause of injuries. When the height of landing increased, the impact force is increase that may be caused more risk of knee injuries (3). Moreover, the study about hop task demonstrated that peak ACL strain occurs at the peak vertical ground reaction force (PVGRF) after initial contact during landing phase (4).

Previous studies have examined on single-leg landing in various tasks including drop landing (5), hopping (6) and stop jump task (7). Peak vertical ground reaction force ranged from 3.7 to 4.5 times body weight (BW) for drop landing (5), 2.45 to 2.52 BW for single-leg hop (6) and approximately 3BW for stop jump task landing (7). For landing in sport, only one study investigated different landing techniques after blocking in volleyball including stick landing, step-back landing and run back landing (8). Nevertheless, this study investigated double-leg landings.

A short time to peak vertical ground reaction force and high loading rate are associated with lower extremity injuries (9). For example, a greater risk of plantar fasciitis occurs as loading rate increased (10).

Sepaktakraw spike landing is susceptible to injury due to high impact on a single-leg landing. To the authors' knowledge, no previous research has investigated ground reaction forces and loading rate during sepaktakraw spike landings. Understanding these ground reaction forces and loading rate can provide more insights of sepaktakraw spike landings and may help to reduce potential injuries. Therefore, the purpose of this study was to investigate differences of ground reaction forces and loading rate during different sepaktakraw spike landings. We hypothesized that PVGRF and loading rate of these sepaktakraw spikes would be different.

## METHODS

### Participants

Ten collegiate male sepaktakraw athletes with experienced more than 1 year ( $\bar{x}_{age}$   $19.6 \pm 2.8$  years,  $\bar{x}_{weight}$   $61.4 \pm 7.2$  Kg and  $\bar{x}_{height}$   $1.74 \pm 0.04$  m) volunteered for this study. Prior to data collection, participants read and signed consent forms that followed the guidelines of the Mahidol University Institutional Review Board (MU-IRB). The inclusion criteria were: 1) able to perform all 3 types of spike and 2) has more one year of experience. Participants were excludes if they had lower extremity injuries in the past 6 months or other injuries/conditions that limited performance.

### Experimental Design

A force platform (Kistler Type 9286BA, Kistler Group, Winterthur, Switzerland) connected with a 3-D motion analysis system (Smart DX5000, BTS Bioengineering, Italy) was used to collected GRF data at the sampling rate of 1,600 Hz. A 2-minute warm up was performed according to individual routine training program. After warmed up, all athletes were instructed to perform sepaktakraw spikes on a takraw ball which was suspended from a fixed bar. The order of spike was randomly assigned to the participants. The height of a ball was adjusted based on individual preference and was normalized with participants' height. The ball heights of RS, HS and SS were  $127.4 \pm 7.63$ ,  $120.1 \pm 6.79$  and  $116.8 \pm 3.46\%$  body height, respectively. One-minute rest was allowed between trials. Five successful trials of each spike landing were averaged and analyzed. A successful trial was defined as a trial that the first leg landing on the center of a force plate. Visual3D software (C-motion, Germantown, MD, USA) was used for signal processing and derives peak vertical GRF (PVGRF) and other parameters including time to peak vertical ground reaction force (TTPF) and loading rate (LR). Loading rate were determined form the ratio of peak ground reaction force and time to peak force (11). GRF data were filtered using a Butterworth filter with optimal cut-off frequencies of 20 Hz (12). Initial contact (IC) was defined when the threshold of VGRF is greater than 20 N. Ground reaction forces were normalized with body weight.

### Statistical analysis

The SPSS for Windows (version 17.0, Chicago, IL, USA) were used for all statistical analysis. Shapiro-Wilk test revealed normality of all data. As a result, one-way repeated measurement ANOVA was employed to compare PVGRF, TTPF and LR among three different spike landings. Tukey post hoc analysis was used to determine significant difference among the main effect. The significant test was set at  $p < 0.05$ .

## RESULTS

There were significant differences of all variables among three spike landings (Table 1). Post-hoc comparison showed significant differences between RS vs. HS and RS vs. SS but no significant difference between HS and SS ( $p<0.05$ ).

Table 1 Mean  $\pm$  SD of all force variables during sepaktakraw spike landings.

Variables	RS	HS	SS	F-value	p
PVGRF (BW)	3.97 $\pm$ 0.76	2.35 $\pm$ 0.57*	2.83 $\pm$ 0.44*	21.528	0.000
TTPF (ms)	30 $\pm$ 10	80 $\pm$ 20*	90 $\pm$ 30*	23.414	0.000
LR (BW/s)	158.8 $\pm$ 64.8	33.8 $\pm$ 13.3*	35.4 $\pm$ 14.4*	31.851	0.000

PVGRF: Peak vertical ground reaction force; TTPF: Time to peak force; LR: Loading rate

\*significant difference compared to RS ( $p < 0.05$ )

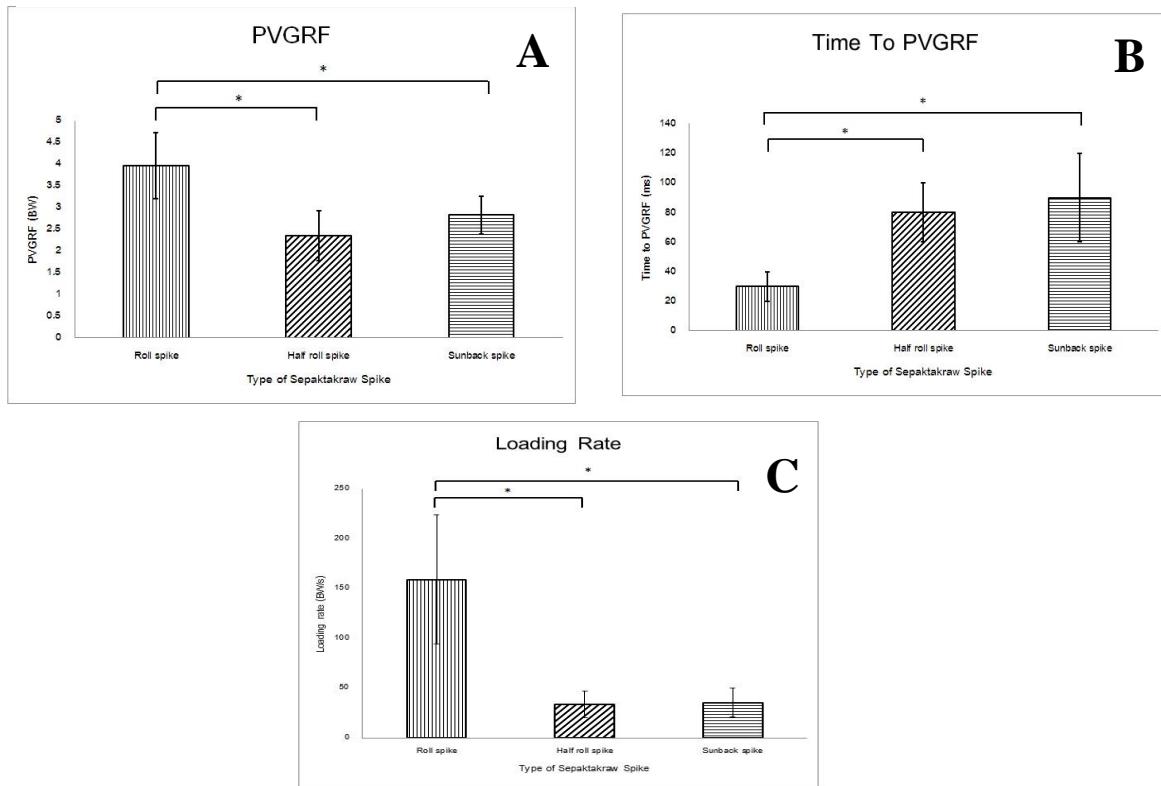


Figure 1 Peak vertical ground reaction force (A), time to peak ground reaction force (B) and loading rate (c) during three different sepaktakraw spike landings. \*Significant difference compared to RS ( $p < 0.01$ )

## DISCUSSION

The purpose of this study was to investigate and compare peak vertical ground reaction force, time to peak force and loading rate of different sepaktakraw spike landings. We hypothesized that these spikes would exhibit differences of these parameter among different spike landings. The results of this study partially

support the hypothesis with significant differences found between roll spike vs. half-roll spike and roll spike vs. sunback spike landings. However, there was no significant difference between half-roll spike and sunback spike landings.

As we expected, peak vertical ground reaction force of RS landing has the greatest force ( $3.97 \pm 0.76$  BW) whereas SS has the lowest peak force ( $2.83 \pm 0.44$  BW). Surprisingly, a HS landing has the lowest peak ground reaction force ( $2.35 \pm 0.57$  BW). The differences between roll spike and the other two spike landings may be because of the position of the body since roll spike requires higher jump to perform a full summersault to kick a ball. Additionally, we observed that when players performed RS, they landed with the same kicking leg. On the contrary, the other spike landings, they did not land on the kicking leg. Yeow et al. (2010) reported that as the height of box increased from 0.3 to 0.6 meters, PVGRFs of single-leg drop landing were increased from 3.7BW to 4.5BW (5). Nevertheless, these values are not comparable to the current study due to different motion and varied vertical distance of the foot position to the floor of each spikes.

Similar to PVGRF, RS landing shows the fastest time to reach peak vertical ground reaction force (30 ms) as compared to HS (80 ms) and SS (90 ms). Previous study suggests that pre-activation for shock absorption occurs within the first 50 ms of landing (9). The time to peak force of RS landing falls in the same range of volleyball spike landing which is 10 - 45 ms after initial ground contact (Cronin et al., 2008). Decreased time to peak force does not allow neuromuscular system enough time to respond to the forces generated upon landing. Therefore, it is plausible that RS landing has more risk of musculoskeletal injury than the other two spike landings. Future study should investigate pre-activation of muscle activities in these spike landings.

RS landing has the greatest loading rate ( $158.8 \pm 64.8$  BW/s) as we presumed as compared to HS ( $33.8 \pm 13.3$  BW/s) and SS ( $35.4 \pm 14.4$  BW/s). Loading rate value of RS is slightly lower than the previous report for collegiate male athletes that performed a drop landing from a height of 60 cm box ( $162.11 \pm 60.84$  BW/s) (13). Nevertheless, it is difficult to select the height of the foot from the ground in the current study. The high loading rate magnitude of RS comes from both high peak vertical ground reaction force and short time to peak force. A high loading rate may contribute to soft and hard tissue of the lower extremities injuries particularly repetitive over time (14). Interestingly, loading rates of HS and SS landings were much significant lower than RS (approximately 80%). Although RS landing creates potential risk of injury, it provides greater chance score and avoids blocking from the opponent in a competition. As a result, landing technique training should be incorporated in sepaktakraw training program to reduce low loading rate which may be beneficial.

Based on the results of this study it is suggested that roll spike may be at high risk of injury as compared to the other two techniques. Nevertheless, this study is strictly focused on ground reaction forces and its parameters. Whether these parameters are associated with injury requires the longitudinal study between loading rates in sepaktakraw landings and lower extremity injury incidences. Future study should also investigate kinematics of lower extremity during sepaktakraw spike landing.

## CONCLUSION

Roll spike landing has the greatest peak ground reaction force, time to reach peak force and loading rate as compared to other sepaktakraw spike landings. Roll spike landing is prone to lower extremity injury; however, future investigation is warranted to determine the association between these force parameters and injuries.

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