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# The effect of Clarke's angle variability on the static and dynamic balance of different sports

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## ABSTRACT

**Background:** Flatfoot affects postural control by altering the biomechanics of the lower limb, sensory input, and proprioception. Poor static and dynamic balance can influence the physical performance of competitive sports athletes and increase the risk of lower limb injury. Footprint analysis using Clarke's angle (CA) is easy to perform and has good diagnostic performance as an alternative flatfoot assessment for a large athlete population. Our study aims to determine the effect of CA variability on the static and dynamic balance of different sports using the one-leg stance (OLS) and star excursion balance test (SEBT).

**Methods:** This is an analytic observational study with a retrospective cohort design. Medical record data from 209 athletes' feet from 11 sports were collected to determine the subjects' characteristics and research variables. Curve estimation and regression tests were performed to assess the effect of CA variability on the OLS and normalized reach distance of SEBT (NSEBT).

**Results:** The mean CA of all athletes was 44.82±11.14º. The mean time of OLS of all athletes was 47.78±40.54 seconds. The least and the farthest average normalized reach distance was done in the anterolateral direction (79.06±11.88 %) and posterior direction (93.45±18.98 %). There is no effect of CA variability on the OLS of all sports, male and female athletes. There is an effect of CA variability on the OLS of Wushu athletes, also on the NSEBT of whole athletes (lateral, posterolateral, posterior, posteromedial directions; male athletes (posterolateral direction); female athletes (anteromedial direction); and different sports, includes athletic (anterolateral, lateral, posterolateral, posterior, posteromedial, medial, anteromedial direction); fencing (anterolateral direction); and running (anterolateral, lateral, posterior, posteromedial, medial, anteromedial, composite directions).

**Conclusion:** Clarke's angle variability significantly affects the static balance of Wushu athletes and the dynamic balance of athletes in athletics, fencing, and running.

**Keywords:** Clarke's angle, flatfoot, one-leg stance, star excursion balance test.
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## INTRODUCTION

A flatfoot or pes planus is a disorder in which the medial longitudinal arch of the foot is collapsed. The medial longitudinal arch of the foot provides an essential element of stability and resistance to the foot and is the main load-bearing and shock-absorbing structure of the foot.[1]

Several etiologies have been suggested to cause flatfoot, including ligamentous laxity, weakness or overactivity of the leg muscles, posterior tibial tendon dysfunction, and other conditions that impair the range of motion and muscle activity of the ankle joint. Age, gender, obesity, footwear, and physical activity were risk factors for flatfoot.[2]

The prevalence of flatfoot in adults ranges from 5% to 20%, and flexible flatfoot is the most common type. The prevalence of flexible flatfoot is 13.6%, with a ratio of 12.8% for males and 14.4% for females.[3]

The incidence of flatfoot differs in each country, which is 20% of the population in the United States and 5% in Saudi Arabia[4]. Several studies in Indonesia showed that 40.4% of 57 college students had flatfoot, 7 out of 28 basketball athletes had flatfoot, and 37.8% of foot cases treated at the Physical Medicine and Rehabilitation Outpatient Clinic in a year were flatfoot.[5]

Flatfoot is diagnosed through clinical assessment, radiographic evaluation, and footprint analysis. Although weight-bearing radiographic evaluation is considered the gold standard for flatfoot diagnosis, footprint analysis is suitable and recommended in some situations, such as screening a large population.[6]

Footprint analysis using Clarke's angle demonstrated good accuracy for flatfoot diagnosis. A previous study demonstrated that Clarke's angle has a sensitivity of 51 – 52%, a specificity of 71 – 75%, an intraclass correlation of 0.9, and a strong correlation with the radiological examination (r > 0.9).[7]

Flatfoot can alter biomechanical forces in the lower limbs and impair sensory input, and proprioception, resulting in postural control changes. The changes in postural control can cause pain, limitation of functional activity, and disturbances of static and dynamic balance.[8]

Static and dynamic balance are important physical performance parameters for competitive athletes. Instability increases the risk of sports-related lower limb injuries by 60-90%. A previous study demonstrated that 14.1% of the 99 athletes who sustained an ankle sprain had flatfoot.[9]

One leg stance is a quantitative measurement of the time to maintain balance in a single stance position with an interclass correlation coefficient of 0.60 - 0.81. Star Excursion Balance Test is a dynamic balance assessment performed by maintaining a single leg stance while the other foot reaches eight different directions. It can assess an athlete's balance condition while practicing or competing with an interclass correlation coefficient of 0.81 - 0.96.[10,11]

Each sport has different foot characteristics related to the specific movement performed and internal and external factors. The effect of foot morphology on the physical performance of competitive athletes is the subject of interest to numerous research. On the other hand, quantifying the foot deformity using Clarke's angle can help clinicians decide on appropriate interventions to improve the physical performance of competitive athletes. Currently, there is no study about using footprint measurement on the physical performance of competitive athletes of different sports. This study aims to assess the static and dynamic balance of athletes of 11 different sports using Clarke's angle obtained from footprint measurement. We hypothesized that the variability of Clarke's angle affects the static and dynamic balance of different sports.

## METHODS

This study is a retrospective analytic observational study using the medical records of athletes. The research samples are 209 feet of athletes aged 17 – 30 (n=209) from 11 different sports. All athletes attended the screening at Sports Clinic dr. Soetomo General Hospital Surabaya at March 2020. All samples fulfilled the inclusion criteria, and the subjects were drawn by a simple random sampling method. The inclusion criteria were the athlete's medical record containing data on the subject and variable characteristics. The exclusion criteria are the medical records that did not contain complete data on the subject and variable characteristics.

Our study protocol has obtained ethical approval from the institutional review board of the author's institution with ethical clearance number 0471/LOE/301.4.2/V/2021. The data collected from medical records of different athletes as age, gender, height, Body Mass Index, sport branches, dominant leg, leg length, history of injury and surgery, physical exercise, Clarke's angle from footprint analysis, time of one leg stance, and normalized reach distance of star excursion balance test.

Descriptive data analysis was performed to determine the subject and variable characteristics using IBM SPSS Statistics 26.0 software. One Sample Kolmogorov – Smirnov test was performed to determine data normality and homogeneity. Regression analysis was performed to observe the effect of Clarke's angle variability on the time of one leg stance and the normalized reach distance of the star excursion balance test. Statistical analysis was conducted at the 0.05 level of significance; thus, $p$-values below 0.05 were interpreted as statistically significant.

## RESULT

### Subject Characteristics

The subjects were 209 athletes' feet, 102 males and 107 females. Subject characteristics are shown in Table 1. The mean age of the subjects is 22.11 ± 3.82. The mean body mass index of the subjects is 23.34 ± 3.84 kg/m$^2$. One hundred and eighty (90.4%) subjects were right-foot dominant. Forty-one (19.61%) athletes had a history of knee injury, and 63 (30.14%) athletes had a history of an ankle injury. Four athletes (1.91%) had a history of knee surgery, and one athlete (0.47%) had a history of ankle surgery. Forty-two (20.09%) athletes had 2-3 times strengthening exercise in a week, 84 (40.19%) athletes had 3-5 times of strengthening exercise in a week, and 83 (39.71%) athletes had more than five times exercise in a week.

### Variable Characteristics

Variable characteristics are shown in Table 2. The mean Clarke's angle of all athletes was 44.82 ± 11.14º. All athletes' mean

**Table 1. Subject characteristics**

| Subject Characteristics | n (%) | Mean ± SD | p |
|---|---|---|---|
| Age (year) | 209 | 22.11 ± 3.82 | 0.962 |
| Gender (male/female) | | | |
| Male | 102 | | |
| Female | 107 | | |
| Height (cm) | 209 | 166.28 ± 7.86 | 0.200 |
| Body mass index (kg/m$^2$) | 209 | 23.34 ± 3.84 | **0.017*** |
| Leg Length (cm) | 209 | 90.91 ± 5.64 | 0.200 |
| Foot domination | | | 0.203 |
| Right | 189 (90.43%) | | |
| Left | 20 (9.56%) | | |
| History of injury | | | |
| Knee | 41 (19.61%) | | 0.208 |
| Ankle | 63 (30.14%) | | 0.340 |
| History of surgery | | | |
| Knee | 4 (1.91%) | | 0.340 |
| Ankle | 1 (0.47%) | | **0.046*** |
| Frequency of strengthening Exercise | | | **0.015*** |
| 1 – 2x/ week | 42 (20.09%) | | |
| 3 – 5x/ week | 84 (40.19%) | | |
| > 5x/ week | 83 (39.71%) | | |

***Significant if p <0.05**

**Table 2. Variable characteristics**

| Variable characteristics | Mean ± SD | *p* |
|---|---|---|
| Clarke's angle (degree) | 44.82 ± 11.14 | 0.200 |
| One-leg stance (second) | 47.78 ± 40.54 | 0.052 |
| NSEBT Anterior (%) | 83.72 ± 12.62 | 0.064 |
| NSEBT Anterolateral (%) | 79.06 ± 11.88 | 0.200 |
| NSEBT Lateral (%) | 79.14 ± 19.66 | 0.200 |
| NSEBT Posterolateral (%) | 89.24 ± 17.54 | 0.090 |
| NSEBT Posterior (%) | 93.45 ± 18.98 | 0.200 |
| NSEBT Posteromedial (%) | 90.86 ± 19.48 | 0.090 |
| NSEBT Medial (%) | 85.90 ± 22.32 | 0.200 |
| NSEBT Anteromedial (%) | 84.27 ± 18.03 | 0.092 |
| Composite SEBT (%) | 85.70 ± 15.11 | 0.052 |

***Significant if $p$ <0.05**

**Table 3. Distribution of sports among subjects**

| Sports | n | Clarke's angle range (degree) |
|---|---|---|
| Athletic | 31 (15.23%) | 7.83 – 60.21 |
| Fencing | 28 (13.34%) | 11.63 – 59.09 |
| Wrestling | 34 (16.19%) | 19.13 – 61.24 |
| Handball | 24 (11.42%) | 27.26 – 55 |
| Hockey | 20 (9.52%) | 12.92 – 54.85 |
| Discus throw | 4 (1.90%) | 16.23 – 45.56 |
| Shot put | 2 (0.95%) | 57.55 – 58.43 |
| Gymnastic | 6 (2.85%) | 23.59 – 59.15 |
| Wushu | 20 (9.52%) | 17.2 – 52.48 |
| Basketball | 16 (7.6%) | 23.8 – 57.98 |
| Running | 24 (11.42%) | 24.14 – 63.73 |

**Table 4. Regression analysis of Clarke's angle variability to the time of one leg stance in all athletes, between genders, and in different sports**

| Gender/ sports (n) | $R^2$ | *p* |
|---|---|---|
| All athletes (209) | 0.015 | 0.381 |
| Male (102) | 0.036 | 0.307 |
| Female (107) | 0.005 | 0.785 |
| Athletic (32) | 0.037 | 0.292 |
| Fencing (28) | 0.135 | 0.332 |
| Wrestling (24) | 0.101 | 0.356 |
| Handball (24) | 0.087 | 0.163 |
| Hockey (20) | 0.032 | 0.447 |
| Disc throw & shot put (6) | 0.789 | 0.097 |
| Gymnastic (6) | 0.370 | 0.500 |
| Wushu (20) | **0.357** | **0.023*** |
| Basketball (16) | 0.023 | 0.859 |
| Running (24) | 0.062 | 0.742 |

**$R^2$: regression coefficient, *significant if $p$ <0.05**

time for one leg stance was 47.78 ± 40.54 seconds. The mean normalized reach distance for each Star Excursion Balance Test direction were 83.72 ± 12.62 (anterior), 79.06 ± 11.88 (anterolateral), 79.14 ± 19.66 (lateral), 89.24 ± 17.54 (posterolateral), 93.45 ± 18.98 (posterior), 90.86 ± 19.48 (posteromedial), 85.90 ± 22.32 (medial), 84.27 ± 18.03 (anteromedial), and 85.70 ± 15.11 (composite), respectively. All variable characteristics had normal distribution (p>0.05).

The distribution of sports among subjects is shown in Table 3. Eleven different sports branches consisting of 31 athletic athletes (15.23%), 28 fencing athletes (13.34%), 34 wrestling athletes (16.19%), 24 handball athletes (11.42%), 20 hockey athletes (9.52%), four discus throw athletes (1.90%), two shot put athletes (0.95%), six gymnastic athletes (2.85%), 20 wushu athletes (9.52%), 16 basketball athletes (7.6%), and 24 running athletes (11.42%). Shot put athletes had the least range of Clarke's angle (57.55 – 58.43°), whereas athletic athletes had the largest range of Clarke's angle (7.83 – 60.21°).

The least normalized reach distance was done by handball athletes in the lateral direction (26.90%), whereas the farthest distances were done by fencing and handball athletes in the posterior and anteromedial directions (141.90%). The least average normalized reach distance was done in the anterolateral direction (79.06 ± 11.88 %), and the farthest average normalized reach distance was done in the posterior direction (93.45 ± 18.98 %).

### The effect of Clarke's angle variability on the static and dynamic balance of competitive athletes

Table 4 shows an effect of Clarke's angle variability on the time of one leg stance. There is no effect of Clarke's angle variability on the time of one leg stance of overall athletes, male athletes, and female athletes.

Table 5 shows that there is an effect of Clarke's angle variability only on the time of one leg stance of Wushu athletes ($R^2$=0.357, p=0.023), also on the normalized reach distance of the SEBT of overall athletes (lateral [$R^2$=0.055, p=0.008], posterolateral [$R^2$=0.055, p=0.008], posterior [$R^2$=0.031, p=0.040], and posteromedial directions [$R^2$=0.033, $p$=0.032]); male athletes (posterolateral direction [$R^2$=0.090, p=0.027]); female athletes (anteromedial direction [$R^2$=0.075, p=0.045]); and different sports, includes athletic (anterolateral [$R^2$=0.128, p=0.044], lateral [$R^2$=0.211, p=0.032], posterolateral [$R^2$=0.292, $p$=0.007], posterior [$R^2$=0.266, $p$=0.011], posteromedial [$R^2$=0.283, p=0.008], medial [$R^2$=0.132, p=0.041], anteromedial [$R^2$=0.133, p=0.040], composite direction [$R^2$=0.227, p=0.024]); fencing (anterolateral direction [$R^2$=0.321, p=0.024]); and running (anterolateral [$R^2$=0.248, p=0.013], lateral [$R^2$=0.182, p=0.038], posterior [$R^2$=0.216, p=0.022], posteromedial [$R^2$=0.266, p=0.010], medial [$R^2$=0.303, p=0.023], anteromedial [$R^2$=0.240, p=0.015], composite directions [$R^2$=0.246, p=0.014]).

## DISCUSSION

The age of the subjects of this study was similar to the previous study by Hahn *et al*. (14-24 years), Dingenen *et al*. (16-27 years), Troester *et al*. (24.5 ± 3.7 years), and Hertel *et al*., (21.9 ± 2 years). Gender also needs to be considered because balance performance can differ based on gender, level of competition, and sports.[11-14]

Most of the subjects were classified as overweight at risk. An increase in body weight can reduce postural stability because the center of gravity of the standing human body lies high above a small base of support. Most subjects have right leg dominance, but previous studies show that leg dominance does not affect balance.[15]

The duration limit of one leg stance in this study is similar to the previous study that shows a 20 – 30-second duration limit gives relevant results but prevents fatigue.

Our findings indicate that Clarke's angle has a significant effect but is not the main factor affecting static balance in Wushu athletes. Huang *et al*. show that Wushu athletes have better static balance and flexibility than running and basketball athletes. The single–leg balance exercise performed by Wushu athletes affects the synergy and strategy for static balance improvement.[16]

Our findings also suggest that Clarke's angle variability does not significantly affect the static balance of other sports. Ostad *et al*. showed no difference in static balance between wrestlers, soccer players, and karate players, while the presence of perturbations makes a significant difference in dynamic balance rather than static balance.[17]

One leg stance assessment with eyes closed eliminates visual input, increases feedback from proprioception, and activates dominant leg muscles to maintain balance through hip and ankle strategy.

In athletes, somatosensory input from the lower leg contributes to postural adaptation, so biomechanical

**Table 5.** Regression analysis of Clarke's angle variability to normalized reach distance of Star excursion balance test at different sports

| Gender/sports | | Anterior | Antero lateral | Lateral | Postero Lateral | Posterior | Postero Medial | Medial | Antero Medial | Composite |
|---|---|---|---|---|---|---|---|---|---|---|
| All athletes | $R^2$ | 0.003 | 0.024 | **0.055** | **0.057** | **0.031** | **0.033** | 0.014 | 0.014 | 0.020 |
| | p | 0.467 | 0.171 | **0.008*** | **0.007*** | **0.040*** | **0.032*** | 0.084 | 0.401 | 0.201 |
| Male | $R^2$ | 0.026 | 0.050 | 0.053 | **0.090** | 0.068 | 0.059 | 0.038 | 0.032 | 0.062 |
| | p | 0.461 | 0.081 | 0.070 | **0.027*** | 0.077 | 0.116 | 0.283 | 0.359 | 0.103 |
| Female | $R^2$ | 0.030 | 0.010 | 0.050 | 0.009 | 0.004 | 0.016 | 0.031 | **0.075** | 0.007 |
| | p | 0.208 | 0.299 | 0.154 | 0.335 | 0.513 | 0.190 | 0.347 | **0.045*** | 0.856 |
| Athletic | $R^2$ | 0.104 | **0.128** | **0.211** | **0.292** | **0.266** | **0.283** | **0.132** | **0.133** | **0.227** |
| | p | 0.071 | **0.044*** | **0.032*** | **0.007*** | **0.011*** | **0.008*** | **0.041*** | **0.040*** | **0.024*** |
| Fencing | $R^2$ | 0.080 | **0.321** | 0.117 | 0.098 | 0.129 | 0.146 | 0.177 | 0.120 | 0.203 |
| | p | 0.146 | **0.024*** | 0.074 | 0.105 | 0.061 | 0.277 | 0.189 | 0.373 | 0.135 |
| Wrestling | $R^2$ | 0.023 | 0.123 | 0.044 | 0.030 | 0.003 | 0.004 | 0.035 | 0.066 | 0.041 |
| | p | 0.698 | 0.260 | 0.234 | 0.331 | 0.763 | 0.732 | 0.289 | 0.142 | 0.734 |
| Handball | $R^2$ | 0.005 | 0.003 | 0.036 | 0.022 | 0.014 | 0.073 | 0.004 | 0.003 | 0.005 |
| | p | 0.755 | 0.795 | 0.376 | 0.490 | 0.863 | 0.451 | 0.774 | 0.792 | 0.755 |
| Hockey | $R^2$ | 0.144 | 0.099 | 0.037 | 0.008 | 0.054 | 0.023 | 0.054 | 0.030 | 0.028 |
| | p | 0.266 | 0.412 | 0.723 | 0.936 | 0.624 | 0.520 | 0.621 | 0.770 | 0.477 |
| Disc throw & | $R^2$ | 0.900 | 0.332 | 0.277 | 0.855 | 0.803 | 0.815 | 0.863 | 0.745 | 0.735 |
| shot put | p | 0.146 | 0.809 | 0.854 | 0.210 | 0.281 | 0.264 | 0.198 | 0.357 | 0.370 |
| Gymnastic | $R^2$ | 0.402 | 0.223 | 0.137 | 0.417 | 0.017 | 0.652 | 0.189 | 0.747 | 0.529 |
| | p | 0.176 | 0.344 | 0.470 | 0.166 | 0.804 | 0.052 | 0.389 | 0.026 | 0.101 |
| Wushu | $R^2$ | 0.000 | 0.121 | 0.117 | 0.125 | 0.023 | 0.143 | 0.199 | 0.152 | 0.033 |
| | p | 0.944 | 0.134 | 0.141 | 0.533 | 0.523 | 0.468 | 0.151 | 0.438 | 0.444 |
| Basketball | $R^2$ | 0.013 | 0.109 | 0.108 | 0.010 | 0.106 | 0.147 | 0.014 | 0.173 | 0.112 |
| | p | 0.917 | 0.473 | 0.214 | 0.717 | 0.219 | 0.142 | 0.662 | 0.291 | 0.206 |
| Running | $R^2$ | 0.158 | **0.248** | **0.182** | 0.120 | **0.216** | **0.266** | **0.303** | **0.240** | **0.246** |
| | p | 0.055 | **0.013*** | **0.038*** | 0.097 | **0.022*** | **0.010*** | **0.023*** | **0.015*** | **0.014*** |

$R^2$: regression coefficient, *Significant if $p < 0.05$.

disturbances such as foot arch alteration do not significantly affect static balance. Vuillerme *et al.* show that athletes were efficient in the integration process of the center of pressure displacement. This process includes re–weighting of sensory input through specific training to provide smooth postural control.[18]

Good dynamic balance is important for an athlete to respond to sudden perturbations, including changing direction when avoiding an opponent, throwing, or kicking a ball. The excessively pronated foot may disrupt somatosensory input through changes in joint mobility, surface contact area, and muscular strategies to maintain a stable base of support at an upright position.

Our findings show that Clarke's angle variability affects the dynamic balance of whole athletes at lateral, posterolateral, posterior, and posteromedial. Dabholkar *et al.* show that flatfoot affects all reaching directions, mostly in the lateral direction. Excessive pronation mechanism tends to collapse the foot arch toward the medial aspect of the foot and reduce the ability to maintain rigid support in a weight-bearing position. This mechanism accounts for reduced dynamic balance in the lateral direction.[19]

Our findings also suggest that Clarke's angle variability affects posterolateral reaching in male athletes and anteromedial reaching in female athletes. Alnahdi *et al.* showed that males have greater reach distance in the anterior, posteromedial, and posteromedial directions. In contrast, Sabin *et al.* showed that males reach farther in the posterior direction than females. Reduction in vision feedback occurred during posteromedial and posterolateral reaching, so postural control depends on non–visual, somatosensory inputs.[20,21]

Gribble *et al.* stated that females perform better at medial and posterior reaching because a wider pelvis structure maintains the center of mass that provides better stability. Females tend to have early pubertal growth maturation, including a somatosensory system at the lower extremities that provides better input for postural control in the anteromedial direction.[22]

Bhat *et al.* showed that long-term athletic training improves neurosensory pathways and stimulates cutaneous nerve receptors or mechanoreceptors in the muscle, ligaments, and joint capsule of the knee and ankle joint, as indicated by improved balance and proprioceptive.[23]

Hertel *et al.* stated that the cavus foot has less plantar contact area, shifting the base of support to the medial and lateral, decreasing cutaneous feedback, and causing compensatory movements. Different foot types can affect the center of pressure excursion because they affect the contact area. The Star excursion balance test quantifies the maximal reaching distance instead of the center of pressure excursion.[11]

Vasconcelos *et al.* show that fencers reach farther in the anterolateral, lateral, and posterolateral directions but are nethermost in the medial direction. Fencers have unique asymmetry in movement; for example, in the basic "on–guard" stance, fencers align their leading foot to the opponent's position while the trailing foot is placed at an angle for stability. This characteristic leads to quadriceps and hamstring muscle co-contraction, as well as plantar flexor and invertor, to maintain dynamic neuromuscular, mainly in the lateral direction. In addition, routine exercise also improves multidirectional stability at the joint.[24]

Paillard *et al.* showed a difference in the anterolateral and lateral direction of wrestlers compared to other sports. Our study also suggests that wrestlers require more balance in the anterior-posterior direction for backward movement while preventing falling backward. A wrestler must effectively maintain a competitive posture to perform the sustained movement to disrupt the opponent's stability.[25]

Clarke's angle variability in handball athletes showed no differences in the reaching distance of SEBT. Routine exercise develops specific sensorimotor challenges that appear important in developing optimal balance in all sports, including handball. Adiguzel *et al.* also showed that handball athletes reach farthest in anterior, anteromedial, posterior, posterolateral, lateral, and anterolateral directions compared to soccer, sprinter, and martial arts athletes.[26]

Several distinct movement characteristics of hockey athletes affect reaching distance, mainly in posterior and posteromedial directions. The movement characteristics include holding a stick with both hands, the body leaning forward, retracted shoulders, neutral neck, and trunk, extended right leg that shows gluteus muscle activity, flexed left hip that shows iliopsoas muscle activity, and also flexed left knee that shows hamstring and quadriceps muscle co-contraction. Postural adaptation of this movement pattern compensates for biomechanical disturbances using synergies and strategies to maintain stability during the excursion, especially in the posterior direction.

The previous study suggests that exercises performed by gymnasts induce neuromuscular adaptations and enhance the rate of force development in a maximal voluntary isometric contraction, enhancing power, motoric performance, and sensory-motor system that improves stability. Neurological adaptation in athletes also induces more efficient postural control by reducing dependency on visual input and relying more on proprioception.[27]

Matthews *et al.* showed that martial arts exercise improves proprioception, neuromuscular control, and greater muscle strength that contributes to better performance in dynamic balance, including backward displacement and cross-leg movement that resembles posterolateral, posterior, and medial reaching movements in SEBT.[28]

Bressel *et al.* demonstrated that basketball players have inferior balance compared to gymnasts and soccer players because basketball player seldom uses one leg to maintain stability and obtain a position from ball and player position cues.[29] Anat *et al*. showed that running is a high-impact and dynamic activity that challenges postural control to maintain the center of mass displacement on a narrow base of support.[30]

These findings also suggest that the dynamic balance test could represent the performance of competitive athletes compared to static balance. On the other hand, this finding suggests providing appropriate intervention to improve the physical performance of competitive athletes in specific sports.

This study has several limitations. First, the medical records of competitive athletes only contain data about strengthening exercise history, but there is no data about the history of balance exercise. Second, the medical record did not mention the position of the competitive athletes of the team sports that may affect the adaptation and exercise pattern. Third, the busy schedule of competitive athletes could decrease their motivation to do the test. Therefore, the small regression coefficient of Clarke's angle variability to static and dynamic balance could be due to other factors, including the history of balance exercise, position in the team, and motivation of the athletes that were not mentioned in the medical record. Further research must be done to explore other factors influencing the balance of competitive athletes.

## CONCLUSION

Our study shows a significant effect of Clarke's angle variability on the start time of the sway in one leg stance in Wushu and the reaching distance of the star excursion balance test in Athletics, Fencing, and Running.

## RESEARCH ETHICS

Ethics approval for this study was obtained from the Health Research Ethics Committee at Dr. Soetomo General Hospital with ethical clearance number 0471/LOE/301.4.2/V/2021.

## CONFLICT OF INTEREST

The authors of this paper do not have any conflicts of interest.

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## AUTHOR CONTRIBUTION

All authors contributed equally in the preparation of the research project, the assembly of data for the research undertaken, conducting statistical analysis, interpretation of results, manuscript preparation, and literature review.

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