

# ความสัมพันธ์ระหว่างความแข็งแรงของกล้ามเนื้อขา และความสามารถในการลุกจากนั่งขึ้นยืนด้วยขาข้างเดียว ในผู้ใหญ่ตอนต้น

## Relationship between lower limb muscle strength and single-leg sit-to-stand performance in young adults

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### บทคัดย่อ

**วัตถุประสงค์:** เพื่อหาวิธีการทดสอบการลุกจากนั่งขึ้นยืนด้วยขาข้างเดียว (single-leg sit-to-stand test, STS) ที่เหมาะสมในด้านจำนวนรอบของการทดสอบ สำหรับใช้ตรวจประเมินความแข็งแรงของกล้ามเนื้อขาในวัยผู้ใหญ่ตอนต้น โดยการหาความสัมพันธ์ระหว่างตัวแปรที่ได้จากการทดสอบ single-leg STS ด้วยการเคลื่อนไหวซ้ำจำนวน 1, 3 และ 5 รอบ (เวลาและดัชนีกำลัง) กับความแข็งแรงของกล้ามเนื้อขาที่ได้จากการทดสอบด้วยเครื่อง isokinetic dynamometer

**วิธีการ:** อาสาสมัครจำนวน 46 คน อายุเฉลี่ย  $21.04 \pm 1.21$  ปี ได้รับการทดสอบ single-leg STS ด้วยการเคลื่อนไหวซ้ำจำนวน 1, 3 และ 5 รอบ เพื่อวัดตัวแปรเวลา (T1-STS, T3-STS และ T5-STS) และคำนวณค่าตัวแปรดัชนีกำลัง (P1-STS, P3-STS และ P5-STS) ของ single-leg STS test วัดความแข็งแรงของกล้ามเนื้อขาโดยใช้เครื่อง Contrex MJ isokinetic dynamometer

**ผลการศึกษา:** ค่าความน่าเชื่อถือของการทดสอบ single-leg STS ด้วยการเคลื่อนไหวซ้ำจำนวน 1, 3 และ 5 รอบ ( $ICC_{3,1}$ ) เท่ากับ 0.68, 0.78 และ 0.90 ตามลำดับ ดัชนีกำลังของการทดสอบ single-leg STS ด้วยการเคลื่อนไหวซ้ำจำนวน 3 และ 5 รอบมีความสัมพันธ์ในระดับสูงกับความแข็งแรงของกล้ามเนื้อขา ( $r=0.753$  และ  $r=0.782$  ตามลำดับ) ในขณะที่ดัชนีกำลังของการทดสอบ single-leg STS จำนวน 1 รอบ มีความสัมพันธ์กับความแข็งแรงของกล้ามเนื้อขาในระดับปานกลาง ( $r=0.687$ ) ตัวแปรเวลา (T1-STS, T3-STS และ T5-STS) มีความสัมพันธ์กับความแข็งแรงของกล้ามเนื้อขาในระดับต่ำถึงปานกลาง ( $r=-0.459$   $r=-0.487$  และ  $r=-0.573$  ตามลำดับ)

**สรุปผลการศึกษา:** ตัวแปรดัชนีกำลังของการทดสอบ single-leg STS มีความสัมพันธ์กับความแข็งแรงของกล้ามเนื้อขาในระดับที่สูง ดังนั้นตัวแปรดัชนีกำลังที่ได้จากการทดสอบ single-leg STS จึงสามารถใช้เพื่อทำนายความแข็งแรงของกล้ามเนื้อขาได้ การทดสอบ single-leg STS แบบ 3 รอบ มีความเหมาะสมในการทดสอบจริงมากที่สุดเนื่องจากใช้เวลาในการทดสอบน้อยและมีความน่าเชื่อถือของการทดสอบในระดับดีเยี่ยม

**คำรหัส:** การทดสอบลุกจากนั่งขึ้นยืนด้วยขาข้างเดียว ความแข็งแรงของกล้ามเนื้อขา ความสัมพันธ์ ดัชนีกำลัง

## ABSTRACT

**Objective:** The purpose of this study was to determine the appropriate protocol of the single-leg sit-to-stand (STS) test in terms of number of repetitions for assessment of the lower limb muscle strength in young adults by exploring relationship between variables obtained from the 1, 3 and 5 repetitions single-leg STS tests (time to complete and power index of the STS test) and lower limb muscle strength obtained from an isokinetic dynamometer.

**Materials and methods:** Forty-six healthy participants with mean age of  $21.04 \pm 1.21$  years participated in the study. Each participant performed 1, 3, and 5 repetitions of single-leg STS test. Time (T1-STS, T3-STS and T5-STS) and power index (P1-STS, P3-STS and P5-STS) were measured during each repetition of the single-leg STS test. Lower limb muscle strength was measured by a Contrex MJ isokinetic dynamometer.

**Results:** The intraclass correlation coefficients ( $ICC_{3,1}$ ) values of the time to complete the 1, 3 and 5 repetitions single-leg STS test were 0.68, 0.78 and 0.90, respectively. P3-STS and P5-STS were highly correlated with lower limb muscle strength ( $r=0.753$  and  $r=0.782$ , respectively) while P1-STS was moderately correlated with lower limb muscle strength ( $r=0.687$ ). T1-STS, T3-STS and T5-STS had poor to moderate correlations with lower limb muscle strength ( $r=-0.459$ ,  $r=-0.487$ , and  $r=-0.573$ , respectively).

**Conclusion:** Power index of the single-leg STS test had strong relationship to the lower limb muscle strength. Therefore, the power index obtained from single-leg STS test can be used to predict strength of the lower limb muscles. The most suitable number of repetitions when performing the single-leg STS test was 3 repetitions as it required less time to administer and has excellent reliability.

**Keywords:** Single-leg sit-to-stand, lower limb muscle strength, correlation, power index

## INTRODUCTION

Strength of lower limb muscles can be assessed directly using standard equipment such as force transducers and isokinetic dynamometry.<sup>1</sup> However, these devices are expensive and time-intensive for used in clinical settings. Functional tests, such as a sit-to-stand (STS) test, do not require expensive equipment and are usually quick to administer. A traditional two-leg STS test has been used to evaluate lower-limb muscle strength in elderly and people with disabling disease related to lower limb muscle strength such as knee osteoarthritis, knee arthroplasty and hemiparesis.<sup>2-4</sup> Hughes et al<sup>5</sup> reported that older adults used greater proportion of quadriceps muscle strength capability than young adults (78% and 34% for older and young adults, respectively) to perform the same STS task. The STS performing with double leg support is appropriate and safe protocol for elderly and people with balance related problems.<sup>6</sup> However, the traditional STS test may not be appropriate for assessing

lower limb muscle strength in young adults because they have upper limit of a capability to achieve the test (ceiling effect) toward maximum value.<sup>7</sup>

Wongsaya and Chamnongkitch<sup>8</sup> developed a new functional test (single-leg STS test) for evaluating knee extensor muscles strength in young adults. It was proposed that STS performed with single leg support would increase challenge of the test because it requires higher amount of knee extensor muscle force to control movement of the whole body similar to a single-leg squat.<sup>9</sup> Power index was used to represent the rate at which work is performed or the force that the lower limb muscles generate to move a body through the distance during the STS movement in a unit of time.<sup>10</sup> Power index of a 5 repetitions single-leg STS test (calculated from body mass, thigh length and time to complete a STS test) was found to be highly correlated with maximum isometric voluntary contraction (MVC) force of the knee extensor

( $r=0.83$ ) while lower correlation was found ( $r=0.76$ ) for the power index of a 10 repetitions single-leg STS test. No correlation was found between STS time and knee extensor muscle MVC.<sup>8</sup>

Several previous studies attempted to explore the relationship between lower-limb muscle strength and variables of the STS test. However, the relationship between STS test variables and lower-limb muscle strength is still unclear. Jones et al<sup>11</sup> reported a high correlation ( $r=0.71$  and  $0.78$  for men and women, respectively) between the number of completed standing in a 30-second two-leg STS test and leg press strength (one repetition maximum) in the elderly. In contrast, McCarthy et al<sup>12</sup> reported low to moderate correlation between knee and hip extensor muscle torques and both of the time to complete a 5 repeated two-leg STS test ( $r = -0.29$  for hip extensors and  $-0.46$  for knee extensors) and the number of completed STS in a 30 second STS test ( $r = 0.33$  for hip extensors and  $0.44$  for knee extensors). In addition, Takai et al<sup>13</sup> reported that power index of the two-leg STS test was highly correlated with MVC force and cross-sectional area of the quadriceps muscle in the elderly. Chen et al<sup>14</sup> reported that thigh muscle volume measured by MRI was positively correlated with the anthropometric data (including body height, body mass, waist size, and thigh circumference).

Findings from these previous studies<sup>8, 12, 13</sup> suggested that several factors may affect the single-leg STS performance. Performance in STS test may be influenced by several other factors besides lower limb muscles strength such as subject's physical characteristics (body mass, height, muscle size and muscle lever arm). Therefore, using muscle strength to body mass ratio may be more appropriate for exploring the relationship between single-leg STS variables and lower limb muscle strength. Performing the single-leg STS test with too many repetitions may induce fatigue to leg muscles.<sup>12</sup> Thus, reducing the number of repetitions may result in higher level of correlation between STS variables and muscle force. In addition, muscle strength obtained from isometric test may not represent actual muscle function during STS movement.<sup>15</sup> Finally, other leg muscles besides the knee extensors may also contribute to the single-leg STS performance.<sup>16</sup> Therefore, the purpose of this study was to determine the appropriate protocol to be used when performing the single-leg STS test in terms of number

of repetitions for assessment of the lower limb muscle strength in young adults by exploring relationship between variables obtained from the 1, 3 and 5 repetitions single-leg STS tests (time to complete and power index of the STS test) and lower limb muscle strength obtained from an isokinetic dynamometer. According to concurrent validity concept<sup>17</sup>, if variables obtained from the single-leg STS test are highly correlated with muscle strength, such variable can be used to predict strength of the lower limb muscles.

## METHODS

Forty-six healthy young adults (23 males and 23 females) with mean age of  $21.04 \pm 0.21$  years participated in the study. The required sample size was calculated based on a previous study by McCarthy et al<sup>12</sup> using a G\*Power 3.1.5 program. To achieve 80% statistical power with an alpha level of 0.05 for correlation test, a minimum of 46 participants were required. Participants were included in the study if they were in age range of 18-25 years and free from neurological or musculoskeletal disorders. Potential participants were excluded if they were athletes or advanced weight trainers. All participants were screened for balance impairment by a single limb stance test.<sup>18</sup> Their demographic data are shown in Table 1. The study protocol was submitted for approval by the Research Ethics Committee, Faculty of Associated Medical Sciences, Chiang Mai University. Participants were informed not to take part in any vigorous exercise within 48 hours<sup>19</sup> and not to take alcohol, caffeine or medications which could affect physical performance within 24 hours before the testing day.

Prior to the test, participants' physical characteristics (e.g. body mass, body height, thigh length, lower leg length, and thigh circumference) were collected. Data collection procedure was divided into two sessions. In the first session, the single-leg STS tests with different repetitions (1, 3, and 5 repetitions) were performed in random order. Single-leg STS was performed using the dominant leg for support which was determined by leg dominance tests<sup>20</sup> (the leg used to kick a ball, step on bug, write a word with the foot, and take a step forward). The participants sat on a chair with their arms across their chest. The seat height was adjusted to 110% of the participants' lower leg length.<sup>21</sup> The knee joint at starting position was set at  $100^\circ$  of flexion for the tested

**Table 1.** The demographic characteristics of the participants (N=46).

Variables	Male (N=23)	Female (N=23)	Total (N=46)
Age (yr)	20.83±1.40 (19-23)	21.26±0.96 (20-24)	21.04±1.21 (20-24)
Height (m)	1.71±0.05	1.58±0.04	1.64±0.08
Mass (kg)	60.65±5.12	51.89±5.66	56.27±6.94
BMI (kg/m <sup>2</sup> )	20.70±1.75	20.86±2.16	20.78±1.94
Thigh length (cm)	39.50±2.02	38.65±2.13	39.08±2.10
Thigh circumference (cm)	51.02±3.17	50.96±3.71	50.99±3.41

Note: values are mean±SD

(dominant) knee. The untested (non-dominant) leg was lifted just above the floor without moving the leg forward or backward and was not allowed to contact the floor during the test. The participants were instructed to stand up with full knee extension and sit down until their buttock was in contact the chair before starting the next repetition (Figure 1). They were allowed to perform one trial to be familiarized with the task. For the actual test, the participant performed the single-leg STS test with maximum effort as fast as possible. The time (T-STS) was recorded using a stopwatch. Recording time started with the word “go” and stopped when the participant sat fully on the chair of the last repetition. For each of the 1, 3 and 5 repetitions single-leg STS tests, the participant performed 2 trials with resting period of 3 minutes between the trials. The trial with less duration of time was recorded for data analysis. The power index of the STS test was calculated from the following formula.<sup>13</sup>

$$\frac{\text{body mass} \times \text{thigh length} \times 9.81 \times \text{number of STS rep}}{\text{Timed STS}}$$

The second session was administered on the next day. A Contrex MJ isokinetic dynamometer (CMV AG, Dubendorf, Switzerland) was used for measuring strength of the lower limb muscles including hip flexor/extensor, knee/extensor, and ankle plantar flexor/dorsiflexor muscles in random order. Prior to the test, the participants performed a regular warm-up by stretching lower limb muscles and were practiced with submaximal concentric contraction for familiarity. The tested positions were set according to Negahban et al’s study (Figure 2).<sup>22</sup> For

each joint, the participants performed five repetitions of maximal concentric contraction with no rest using reciprocal muscles of a joint in given movement direction.<sup>22</sup> The participants performed 2 trials of testing with resting period of 2 minutes between trials to avoid fatigue. The highest maximal peak torque of the two trials were averaged and normalized with body mass (peak torque to body mass ratio) for data analysis. After a five-minute rest period, strength measurement of the next random ordered muscle group was performed using the same testing procedure. All testing trials were performed at the angular velocity of 60°/s.<sup>22</sup>

Test-retest reliability of the variables obtained from the 1, 3 and 5 repetitions single-leg STS test (time to complete the STS tests) were determined. Ten participants were randomly chosen from all participants for test-retest using the same testing protocol. Participants were retested two day apart. Intraclass correlation coefficient, ICC<sub>(3, 1)</sub>, was used to determine the test-retest reliability.

### Statistical Analysis

Descriptive statistics were used to describe participant’s demographic data as mean and standard deviation. Pearson product moment correlation coefficient statistics were used to determine the relationship between single-leg STS test variables and lower limb muscle strength variables. All statistical analyses were tested using SPSS version 16 for Windows. The significant level was set at 0.05 for all statistical tests.

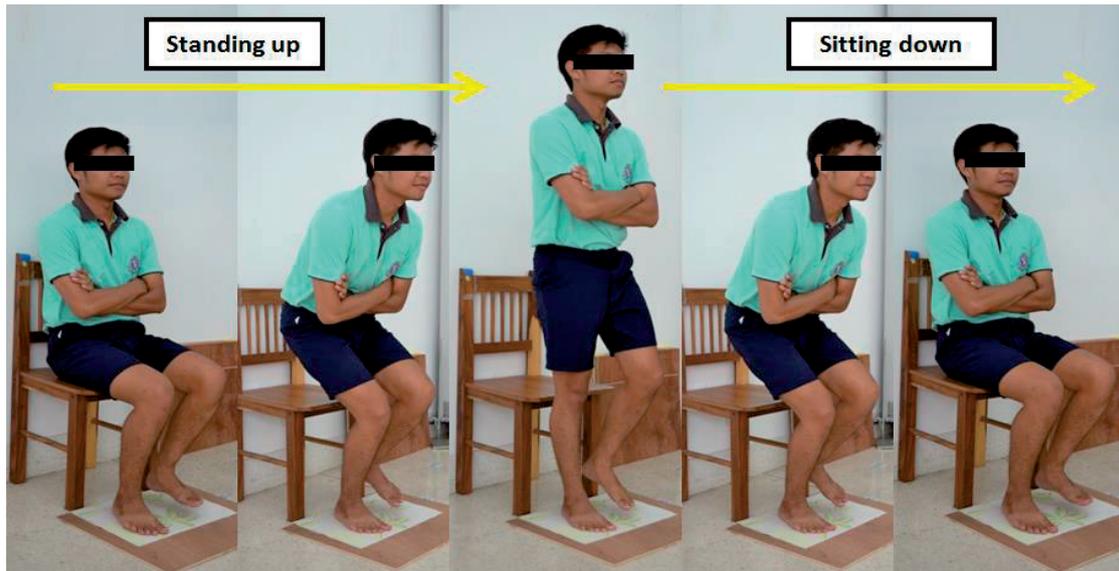


Figure 1. A sequence of one repetition of single-leg STS movement.



Figure 2. Isokinetic testing of the lower limb muscles.

**Table 2.** Time to complete single-leg STS test and power index of single-leg STS test.

Variables	Male (N=23)	Female (N=23)	Total (N=46)
T1-STS (second)	2.07±0.21	2.23±0.23	2.15±0.23
T3-STS (second)	5.96±0.48	6.45±0.59	6.21±0.59
T5-STS (second)	10.01±0.93	11.08±1.07	10.54±1.13
P1-STS (watt)	114.21±13.80	88.94±14.50	101.58±18.95
P3-STS (watt)	118.55±11.69	92.13±14.09	105.34±18.50
P5-STS (watt)	117.76±11.00	89.50±13.57	103.63±18.80

Note: values are mean±SD

## RESULTS

### Reliability Study

The intraclass correlation coefficients (ICC<sub>(3,1)</sub>) values of the time to complete the 1, 3 and 5 repetitions single-leg STS test (T1-STS, T3-STS, and T5-STS) were 0.68, 0.78, and 0.90, respectively.

### Time and Power Index of Single-leg STS Test

The mean time to complete the 1, 3, and 5 repetitions single-leg STS test (T1-STS, T3-STS, and T5-STS) were 2.15±0.23, 6.21±0.59, and 10.54±1.13 seconds, respectively. The mean power index of the 1, 3 and 5 repetitions single-leg STS test (P1-STS, P3-STS, and P5-STS) were 101.58±18.95, 105.34±18.50 and 103.63±18.80 Watts, respectively as shown in Table 2.

### Peak Torque and Peak Torque to body Mass Ratio of lower limb Muscles

The mean peak torque of the hip flexor/extensor, knee flexor/extensor and ankle dorsiflexor/plantar flexor muscle groups were 65.31±24.81, 169.23±49.38, 87.70±29.02, 114.68±31.60, 19.06±5.67 and 86.26±27.56 Newton-meter (Nm), respectively. The mean peak torque of body to mass ratio of the hip flexor/extensor, knee flexor/extensor and ankle dorsiflexor/plantar flexor muscle groups were 1.14±0.37, 2.98±0.71, 1.54±0.41, 2.02±0.41, 0.34±0.08, 1.52±0.40 Nm/kg, respectively as shown in Table 3.

### Correlation Between Variables Obtained from the Single-leg STS Test and lower limb Muscle Strength

All lower limb peak torque to body mass ratios was negatively correlated with all T1-STS, T3-STS, and T5-STS except the knee extensor that was not correlated with T1-STS (Table 4). All lower limb peak torques were positively correlated with all P1-STS, P3-STS, and P5-STS. The level of relationship between lower limb muscle strength and power index were higher than the level of relationship between lower limb muscle strength and Time STS variables as shown in Table 4.

## DISCUSSION

The lower limb muscle strength revealed a high correlation with power index of the single-leg STS test but low to moderate correlation with the time to complete single-leg STS test ( $r=0.604$  to  $0.782$  vs  $r=-0.286$  to  $-0.573$ ).<sup>23</sup> This result agrees with the findings of previous studies.<sup>8, 13</sup> Wongsaya and Chamnongkich<sup>8</sup> reported no correlation between MVC and time but high correlation between MVC and power index. It can be noted that the correlations were found when body mass and thigh length were included in the power index formula. These results suggested that body size affected the relationship between muscle peak torque and power index of the STS task. Although this study used body mass to normalize with peak torque, it was not sufficient to find linear relationship with only time to complete single-leg STS test. Takai et al<sup>13</sup>

**Table 3.** Peak torque and peak torque to body mass ratio of lower limb muscles.

Variables	Male (N=23)	Female (N=23)	Total (N=46)
<b>Peak torque (Nm)</b>			
Hip flexor (HF)	88.38±8.73	42.24±8.39	65.31±24.81
Hip extensor (HE)	209.07±31.64	129.40±25.83	169.23±49.38
Knee flexor (KF)	111.56±19.91	63.84±11.68	87.70±29.02
Knee extensor (KE)	138.17±22.37	91.19±19.73	114.68±31.60
Ankle dorsiflexion (AD)	23.93±3.12	14.19±2.55	19.06±5.67
Ankle plantar flexion (AP)	107.25±21.13	65.23±13.67	86.26±27.56
<b>Peak torque to body mass ratio (Nm/kg)</b>			
Hip flexor (HF)	1.46±0.16	0.82±0.19	1.14±0.37
Hip extensor (HE)	3.46±0.55	2.50±0.48	2.98±0.71
Knee flexor (KF)	1.84±0.32	1.24±0.24	1.54±0.41
Knee extensor (KE)	2.28±0.30	1.76±0.34	2.02±0.41
Ankle dorsiflexion (AD)	0.40±0.05	0.28±0.05	0.34±0.08
Ankle plantar flexion (AP)	1.78±0.38	1.26±0.22	1.52±0.40

Note: values are mean±SD

**Table 4.** Correlation between variables obtained from the single-leg STS test and lower limb muscle strength variables.

	Peak torque to body mass ratio					
	HF	HE	KF	KE	AD	AP
T1-STS	-0.396**	-0.334*	-0.365**	-0.187	-0.459**	-0.378**
T3-STS	-0.487**	-0.454**	-0.478**	-0.286*	-0.429**	-0.480**
T5-STS	-0.573**	-0.459**	-0.534**	-0.361**	-0.517**	-0.455**
	Peak torque					
	HF	HE	KF	KE	AD	AP
P1-STS	0.685**	0.654**	0.687**	0.664**	0.671**	0.604**
P3-STS	0.739**	0.712**	0.753**	0.732**	0.672**	0.650**
P5-STS	0.782**	0.706**	0.775**	0.743**	0.710**	0.635**

Note: \*\*Correlation is significant at  $p < 0.01$

\*Correlation is significant at  $p < 0.05$

indicated that power index of the STS test is more useful to assess knee extensor strength than the time to complete STS variable.

Ferrucci et al<sup>24</sup> reported that the relationship between time to complete a 5-repeated chair stands and knee extensor and hip flexor force was nonlinear if knee extensor and hip flexor force were greater than 98 Newton (N) and 147 N, respectively. All participants in the present study were young individuals having mean knee extensor strength of 290 N (Converting from Nm unit). All male and some female participants had hip flexor strength above 147 N (range 77–279 N). Therefore, it is not surprising that the relationship between time variables and lower limb muscle strength in this study was not found. Moreover, Csuka and McCarthy<sup>25</sup> reported that time to complete 10-repeated sit-to-stand could not differentiate between men and women with different knee extensor strength. Results of the present study confirmed those of the previous studies<sup>8, 13, 24, 25</sup> that time to complete the STS test alone is not appropriate for evaluating lower limb muscle strength.

In the present study, the correlation values of all lower limb muscles strength and power index were about the same level. These results indicated that the power index obtained from single-leg STS test may be used to predict all leg muscles. The results are in contrast with our hypothesis of present study that the knee extensor would have a highest correlation with variable obtained from single-leg STS movement. These could be due to the fact that all leg muscles play the important role in standing up using one leg. Based on an electromyography (EMG) study by Khemlani et al<sup>16</sup>, several muscles of the lower limb were activated during the STS task. There appears to be functional linkages between movement of the hip, knee and ankle joints and onset of the lower limb muscles activity (rectus femoris, vastus lateralis, biceps femoris, tibialis anterior, gastrocnemius and soleus) while moving from sitting on a chair to standing up.<sup>16</sup> Khemlani et al<sup>16</sup> explained that hip flexor muscles generated hip flexion movement during flexion momentum and momentum transfer phases. Hip extensor muscles worked for slowing down hip flexion before reversal hip extension movement. At the knee joint, knee extension was controlled by knee extensor muscles while knee flexor muscles pulled the shank backward to control stability of the knee. The ankle muscles contributed to postural adjustments and postural

stability during STS task. Similar to other movements of the lower limb such as walking, Winter<sup>26</sup> explained that all three lower limb joints produce cooperatively a net extensor moment to support the lower limb during stance phase.

When considering the appropriate number of repetitions of single-leg STS test, it was found that power index values of the 3 and 5 repetitions single-leg STS test were highly correlated with lower limb muscles strength while power index of the 1 repetition single-leg STS test was moderately correlated with lower limb muscles strength.<sup>23</sup> Moreover, our reliability result revealed that both the 3 and 5 repetitions single-leg STS test were acceptable with excellent reliability level (0.78 and 0.90, respectively).<sup>27</sup> The lower reliability of the 1 repetition single-leg STS test (0.67: good reliability level)<sup>27</sup> may be resulted from large variation in the time to complete the STS movement between the tests and retest trials. Timing in each repetition of the single-leg STS test may be affected by the starting movement of each repetition and faulty movements occurred during the 1 repetition single-leg STS test. Whereas for the 3 and 5 repetitions test, the participants could adjust their movement correctly in the next repetition and the possible faulty movements could be averaged across repetitions. Therefore, performing the single-leg STS test with either 3 or 5 repetitions seems appropriate and they can be used interchangeably. Nevertheless, the 3 repetition single-leg STS test seems more suitable for assessment of lower limb muscle strength than the other test because it requires less movement repetition had excellent reliability level.

The limitation of this present study was that only young adults with age range of 18 to 25 years old were included. Thus, the results of this present study are limited for use in assessment of the lower limb muscle strength only in this particular age-range individuals. Moreover, balance could be one of the important components of the single-leg STS test. Although the participants in this study were considered having normal balance as screened by the single-leg stance test, the single-leg STS is difficult task to perform. Therefore, differences in balance control ability could also influence results of the study. In future study, a more intensive balance test for young participants should be incorporated when determining relationship between single-leg STS performance and lower limb muscle strength.

## CONCLUSION

This study revealed that all lower limb muscle strength had moderate to high positive correlation with power index of the single-leg STS test but low to moderate negative correlation with time to complete single-leg STS test. According to concept of concurrent validity, the power index variable obtained from single-leg STS test can be used to predict strength of the lower limb muscle. The appropriate numbers of repetition of single-leg STS test was 3 repetitions because it requires less movement repetition and had excellent reliability level. The correlation values of all lower limb muscles strength and power index variable were about the same level indicating that

all leg muscles played the important role in standing up using one leg. The single-leg STS test is appropriate for assessment of lower limb muscle strength in young adults and convenient to administer in community setting.

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